Wind Energy Department annual progress report 2003

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Wind Energy Department
Annual Progress Report 2003

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Contents

Introduction

The primary objective of the activities of the Wind Energy Department at Risø National Laboratory is to further the technological development as well as the application of wind energy through research and development, educational activities and knowledge-based commercial services. Hence the overall purpose of our work is The primary objective of the activities of the Wind Energy Department at Risø to meet the needs for knowledge, methods and procedures from government, the scientific community – and the wind turbine industry in particular. Our assistance to the wind turbine manufacturers serves to pave the way for technological development and thus further the exploitation of wind energy worldwide. We do this by means of research and innovation, education, software development, testing and consultancy.
In providing services for the wind turbine industry, we are involved in technology development, design, testing and in the development of procedures for operation and maintenance. We are also involved in the certification of wind turbines, we take part in international wind turbine projects and in the solution of problems encountered in the application of wind energy, e.g. grid connection. A major proportion of these activities are on a commercial basis; consultancy on technology development, planning and implementation of wind energy projects as well as capacity building and institutional development. Other commercial activities are software development, advanced courses, measurement systems development and accredited testing of wind turbines and blades. Finally, there is the approval and certification of wind turbines which is carried out in co-operation with Det Norske Veritas.
The department's activities also include research into atmospheric physics and environmental issues related to the atmosphere. One project in this field concerns the development of an online warning system for airborne bacteria and other harmful substances.
Research and development activities of the Wind Energy Department range from boundary layer meteorology, fluid dynamics and structural mechanics/dynamics to power and control engineering, and wind turbine loading and safety.
The department is organized in programmes according to its main scientific and technical activities.

Research programmes

- Aeroelastic Design
- Wind Energy Systems
- Meteorology
- Wind Turbines

Technical programmes

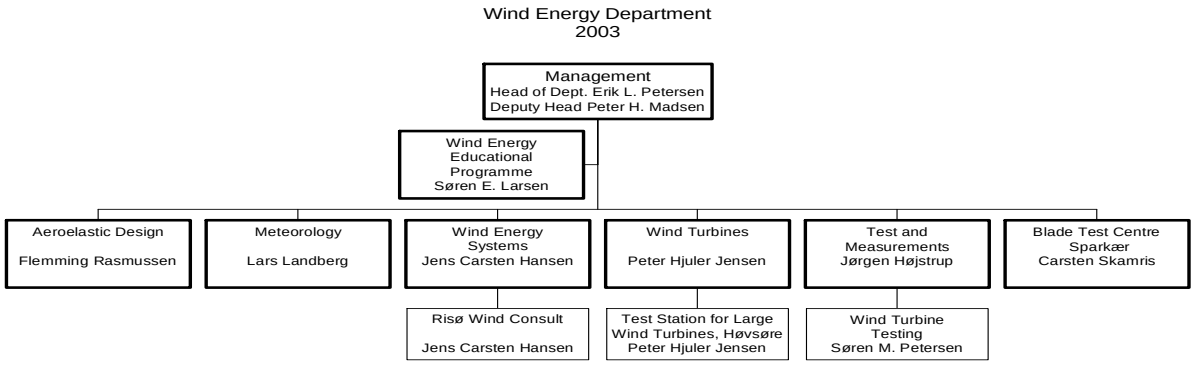
- Test and Measurements
- Blade Test Centre, Sparkær

Commercial services

- The Test Station for Large Wind Turbines, Høvsøre
- Risø Wind Consult
- Wind Turbine Testing

Additionally, the department has established a wind energy educational programme in order to strengthen, manage and coordinate educational activities with respect to our PhD-programme, courses, supervision and guidance at the universities, and courses at other institutions.

In 2003 the department employed a total of 108 man-years, five of which involved PhD students and post-doctoral researchers. The departmental structure in 2003 is illustrated below.



Aeroelastic Design
The key issues of this programme are the development and use of aeroelastic codes, computational fluid dynamics (CFD) codes and software design tools for wind turbine blades and aerofoils. The codes are used for establishing design load bases for wind turbines, in furthering the development of the three-bladed wind turbine concept, and for the development of new wind turbine concepts. Furthermore, this programme undertakes wind tunnel measurements of aerofoil section flows.

Meteorology
The Meteorology research programme is aimed at basic research into boundary layer meteorology and the assessment of wind resources for power generation and wind loads on wind turbines and various other constructions. The programme comprises the development of models and software, field measurements and in-house as well as commissioned assessment studies. We also study environmental problems related to the transport of airborne pollutants and the turbulent exchange of matter during interaction between the atmosphere and terrestrial (or sea) surfaces.

Wind Energy Systems
An important aspiration of this research programme is to lower the cost of energy derived from the wind by optimizing the wind turbine as well as the grid interface and power system operations. Our work includes such topics as system integration, control concepts for wind turbines, electrical components, grid connection and large-scale wind energy penetration, hybrid power supply systems and energy storage combined with renewable energy sources.

Wind Turbines
This research programme conducts strategic and applied research into wind turbine loading and safety, experimental verification, and technical and economic analysis of the utilization of wind energy in grids and in hybrid energy systems. This research

supports our consultancy activities in wind energy projects for Danish and international authorities, organizations, banks and investors. It also supports our participation in the development of international standards.

Test and Measurements
In this technical programme, research is aimed at the development of instrumentation and new methods for experimental determination of wind turbine characteristics, including test methods for the wind turbine industry. This unit also represents departmental expertise in organizing and conducting field meteorological measurements, and in providing instruments as well as data systems and data management for the wind Energy Department and outside clients.

Blade Test Centre, Sparkær
This technical programme is accredited for static and dynamic fatigue testing of wind turbine blades and provides this service to Danish blade manufacturers at our test facility in Sparkær, Jutland.

The Test Station for Large Wind Turbines, Høvsøre
The objective of this service is to establish and operate a test facility for large wind turbines. The test station is situated at Høvsøre, near the west coast of Jutland: This area has excellent conditions with respect to high wind speeds and straightforward wind patterns that are easy to model due to the flat terrain. We can therefore verify both performance and the wind turbine design bases for all operating conditions relevant to large wind turbines.

Risø Wind Consult
This is another commercial service, and in this case we aim to utilize the knowledge and state-of-the-art tools available at Risø in providing consultancy and technical advice for international projects concerning the development and application of wind power technology.

Wind Turbine Testing
Being a commercial service, Wind Turbine Testing offers its expertise in measuring techniques for wind turbine testing at Risø or field measurements for manufacturers.

This annual report presents the department and our results in 2003, including programmes and services, research highlights and other achievements. The report also presents lists of publications, lectures, committees and staff members.

Additional information on the department and our activities can be found on the web; http://www.risoe.dk/amv/. The department's web site is frequently updated.

VEA highlights 2003

The New WAsP project, 2003
The Wind Atlas Analysis and Application Program (WAsP) undergoes continual improvements, and we have just embarked upon a new project which is expected to yield major improvements to the program.
A horizontally homogeneous flow model has been developed, and we intend to use this as the starting point of a more complete solution for neutral atmospheric flow over complex terrain. Unlike previous models, the present work uses general orthogonal coordinates. We have employed a strong conservation form of the model equations in order to allow a robust and consistent numerical procedure. Flow variables are expressed in a transformed coordinate system in which they are horizontally homogeneous. The model utilizes a k-ε turbulence model, and it is part of a new perturbation solver presently being developed. We hope that the new model will prove more accurate than the current standard WAsP program, and that it will also achieve a high execution speed.
The latest version of WAsP, 8.0, was released by the end of 2003. Today, WAsP is considered the industry standard, and there are more than 1,300 WAsP users in more than 90 countries and territories throughout the world. As for licences, 2003 has been the best selling year ever.

Short-term prediction breakthrough
Short-term prediction of wind energy on a time scale of up to 48 hours ahead is very important for the value of wind energy, since it facilitates trading on the electricity markets and the efficient scheduling of power plants. Since 1990, when the first operational short-term prediction system based on numerical weather forecasting was developed by VEA, this issue has been an integral part of the work of the meteorology programme.
In recent years, a more formal collaboration was instituted with the department of Informatics and Mathematical Modelling at the Technical University of Denmark. Under the Zephyr brand name we now use and market both Zephyr/Prediktor (Risø's short-term prediction model) and Zephyr/WPPT (the IMM tool).
In 2003, research in short-term prediction was especially focussed on two projects: the EU-funded Anemos project, and the PSO-funded Ensemble project. A short-term prediction component also found its way into the EU-funded project Cleverfarm, which was finalized in 2003. In the latter case, the short-term prediction module was developed as a tool for the planning of turbine maintenance.

Numerical wind tunnel
This year, our calculation and simulation concept 'the Numerical Wind Tunnel' was widely accepted by the wind turbine industry as a substantial contribution to the design and evaluation process. The concept has played a major role in several projects that have tackled the issue of computing the aerodynamic behaviour of modern large wind turbine designs.
Three current wind turbine designs have been thoroughly investigated using the advanced computational fluid dynamics (CFD) code EllipSys3D. This project was financed by the Danish energy research programme EFP 2002.

Another major breakthrough was achieved in the simulation of the flow around a wind turbine at standstill. It is now possible to extract much more detailed information regarding the spanwise distribution of forces acting on the blades. This is of major importance to the industry as it is fundamental in blade design.

HAWCStab predicts the stability of wind turbines

A new program has been developed at VEA, aimed at investigating the dynamics of wind turbines. HAWCStab is the first numerical tool that uses eigenvalue analysis to predict the limits of a wind turbine's aeroelastic stability. This program calculates eigenfrequencies as well as the damping characteristics of either structural or aeroelastic oscillations of a working wind turbine.

Calculations of aeroelastic damping from HAWCStab – including the effect of the wind's aerodynamic power – have been used already in actual experiments aimed at predicting and understanding observed oscillations of a wind turbine. By animating these oscillations, we have been able to obtain a better understanding of the dynamics of wind turbines as well as the cause of undampened oscillations.

Improved design base for large wind turbine blades

In the course of a project initiated to examine the ultimate strength of bonded joints in wind turbine blades, we have worked with a test set-up for 'mixed mode' fracture growth in bonded joints. This particular set-up also applies to a variety of other composite components. The material properties of the joint have been modelled by a cohesive law, and the fracture growth in large components has been predicted successfully on the basis of test results from small components.

This project also includes an investigation entitled 'Compressive strength of fibre composite blade structures' which has inspired the development of an instrument for measuring local buckling during full-scale testing of wind turbine blades. By using the finite element method, we have successfully simulated the local instability induced by bending the blade. The instability phenomenon has been verified in a full-scale test, performed to the point of collapse.

Offshore wind turbine reliability: optimized and uniform safety

We are currently investigating how the overall structural safety of wind turbines depends not only on the structural reliability of the wind turbine itself, but also on the reliability of control and safety systems. Using data from working wind turbines during the period from 1982 to 2000, we have confirmed the existence of a suspected imbalance between structural reliability and the reliability of safety and control systems.

There has been a limited quantity of data available to this study due to a regrettable decline in reports from manufacturers in the latter years. An improved understanding of the theoretical structural safety seems now to have been established and has led to contributions to the present committee-stage draft for the IEC standard 61400-1 as well as ongoing work on an IEC standard for offshore wind turbines.

Simulation and validation of power systems

The stability of an electric power system as well as security of supply both depend on the reliability of the generators supplying the power. With the increase in wind power utilization, the influence of wind turbines on power system stability grows significantly.

Various models for simulating this influence have been developed by the utilities as well as research institutes and the wind turbine industry. In order to validate a number of these models, we have carried out a series of experiments on a Danish wind farm, comprising six 2 MW wind turbines. Experimental events were subsequently simulated by means of models developed by Risø and Aalborg University in DIgSILENT software, and with models developed by the Danish utility NVE in EMTDC software. These models were developed in a collaboration with NEG-Micon Control Systems, suppliers of control systems for the wind turbines in question. The validation process has provided useful knowledge on the quality of simulation models as well as new ideas for further development.

Stand-alone systems for rural areas

In many Third World countries, there is a need for a power technology, specifically designed for villages that are without connection to the large electrical grids. Due to the climatic as well as economic and technological circumstances of these communities, it is essential that such isolated systems are robust as well as dependable and scalable.

In Denmark, the 11 kW Gaia wind turbine has proven itself with 90 installations since 1995 and an excellent track record. We therefore chose the Gaia wind turbine for this stand-alone system. The wind turbine was modified and attached with a newly developed stand-alone control. The system was subsequently tested and conclusions are that a stand-alone wind turbine combined with a battery storage is a feasible way of procuring energy for remote villages, provided there is ample supply of wind.

National test station for wind turbines in India

For more than a decade, we have been involved in the acceleration of wind power utilization in India. The latest activity is supported by the Danish development agency Danida and concerns assistance to the Indian government institution Centre for Wind Energy Technology, located in Tamil Nadu. The purpose of this project is to establish a national test station with facilities for testing and certification of wind turbines, and the capacity for monitoring their technical performance. The project also includes the preparation of standards and certification rules.

At the end of 2003 a full professional organization has been established, and staff has participated in workshops and on-the-job training with regard to testing, certification, and technical support. The provisional type approval system is fully implemented and a final type approval system, based on international standards, has been completed and is now ready for implementation.

The entire project should be completed by the end of June 2004.

Pollution scenarios

The increased threat of terrorist actions has launched a keen interest in modelling pollution dispersion scenarios. Future targets are expected to be in urban areas, and attacks may include chemical, biological, radiological or nuclear materials and weapons. Another major risk to the urban environment is that of conventional accidents such as industrial plant fires or major transport accidents that may lead to the release of harmful or dangerous substances.

In 2003, Risø entered into an agreement with the Defence Science and Technology Laboratory in Porton Down, England, with whom we have already collaborated on a number of projects. The aim of this particular partnership is to combine Risø's

dispersion model, RIMPUFF (Risø Mesoscale Puff Model), with DSTL's Urban Dispersion Model for emergency management purposes in urban areas.

CO_2 uptake by forests and seas

Since 1996 we have participated in an EU-project, EuroFlux, which looks into the determination of CO_2 uptake by various terrestrial ecosystems.

The Danish EuroFlux research site is an 86 year old beech forest on Zealand. The CO_2 flux is determined by means of the eddy correlation technique using measurements from a tower that extends well above the top of the forest canopy. The research has shown that the net ecosystem exchange is a delicate balance between the photosynthetic assimilation (approximately 1000 gC/m^2/year) and the ecosystem respiration processes.

The forest has a concentrated period of carbon uptake from May to September, but during the remainder of the year there is a considerable loss due to respiration from a large pool of carbon in litter and soil. The assimilation and the respiration both depend on environmental variables such as solar radiation, air and soil temperature and humidity, but in different ways.

The year-on-year variation in carbon figures is important in the assessment of forests as long-term carbon sinks under changing climatic conditions. The annual net uptake over a seven year period (1996-2002) has varied from 71 g C m^{-2} to up to 288 g C m^{-2}. These variations have no apparent correlation to the seasonal averages of the environmental variables.

We have also measured CO_2 fluxes in the North Atlantic within the Arctic circle in October 2003. These measurements have supplemented data compiled on three previous expeditions in the same area at different times of the year. The data collected shows a large temporal and spatial variation in the flux, with the CO_2 flux varying over the seasons, showing a slightly larger ocean uptake in the summer and autumn when algae influence the flux.

It is hypothesized that water temperature and wind are the main factors in controlling the flux during the winter. This hypothesis will be tested in the course of ongoing work. On average, the measurements showed larger fluxes in the Norwegian Sea than in the Greenland Sea, which can be attributed to higher wind speeds. A significant finding has been that the largest fluxes occur at the ice edge.

Høvsøre commenced operation

In 2003, we have erected the final measurement masts and meteorological tower at our Test Centre for Large Wind Turbines at Høvsøre on Jutland's west coast. The masts and towers were also equipped with the necessary instruments in order to commence operations. The measurement system covering a total of five test stands came into full operation in late spring that same year.

During the first year of operation five wind turbines have been tested, from four different manufacturers. The largest turbine to be tested at Høvsøre to date has been a 4.2 MW turbine from Vestas Wind Systems A/S.

Today, Høvsøre is the world's only test station for MW-size wind turbines where wind turbines are erected at the test site for a limited period, usually around a year, and subsequently replaced with new turbines.

Wind measurements from Høvsøre may be viewed online at Risø's website www.risoe.dk under the Wind Energy Department's 'Products and Services'.

Test hall extension at Sparkær

In 2002, the test facilities at Sparkær were improved considerably by the extension of the hall from 42 to 52 metres, thus making it possible to take in wind turbine blades of up to 50 metres in length for testing. The new hall was ready for use in January 2003. The old test stand B, however, had a capacity of only 2,000 kNm for fatigue load testing. It has therefore been replaced in 2003 with a new test stand with a capacity of up to 8,000 kNm. The new test stand weighs 45 tonnes and has been manufactured locally.
With these improvements, Sparkær is now capable of testing 50 m wind turbine blades.

Educational efforts
In 2002 the governmental research institutions in Denmark were called upon to step up their support for higher education, especially within areas where they have special knowledge, due to their field of work.
The Wind Energy Department has responded to this call by a strongly increased effort, covering a broad range of educational activities, the majority of which are aimed at the Danish wind energy industry.
During 2003, we have increased the number of PhD-projects within the department from three to 11, two of which have been financially supported by the wind turbine industry. Two PhD-students obtained their degrees, and six Master of Science projects were concluded that same year. Aside from the university co-operation involved in these projects, the department has participated with lectures and short-term courses at Aalborg University, the Technical University of Denmark, University of Copenhagen and the Herning Institute of Business Administration and Technology. We have participated in three international summer schools and have also been active in the formation of five networks and academies to support the education of young scientists and PhD-students, notably the Danish Academy of Wind Energy and the similar European Academy of Wind Energy.

Development of the offshore wind energy course
In 2003 we completed the development of and implemented Risø's first offshore wind energy course. This is a one week course, and the contents of the course cover the main aspects of a major offshore project from the selection of a favourable site to the operation of the actual wind farm. The topics of the course are:
wind resource assessment,
offshore measurements,
short-term forecasting of wind farm production,
structural loads,
wind turbine foundations,
grid connection, and
wind power plant operation and offshore project certification,

The first course took place at Risø with staff from Taiwan's Industrial Technology Research Institute (ITRI) as participants. The specific purpose of the course in this case was to strengthen the institute in its role as consultants to the Taiwanese authorities on the development of wind energy utilization.

Projects of the Department

Meteorology, MET

Research programme
Head of Programme: Lars Landberg

The objective of the Meteorology programme is to develop and implement methods and models for the determination of wind resources and wind conditions, and all sorts of transport processes in all forms of natural terrain. This is all based on theoretical and experimental research in boundary layer meteorology, climatology and atmospheric flow and turbulence.
The programme encompasses four major focus areas.
• Wind power meteorology which includes research into wind resources, short-term prediction and wind engineering.
• Boundary layer meteorology, consisting of general boundary layer meteorology and the meteorological use of satellite data.
• Remote sensing: Remote measurements by means of SODAR, LIDAR and laser.
• Decision support systems: This area encompasses the development of models for nuclear, radioactive, chemical and biological emergency support.

MET projects

The numerical wind atlas
Programme: MET, project no. 1130 105-1, start date 1.1. 2002.
● Development and application of the numerical wind atlas method. This method combines the Karlsruhe Atmospheric Mesoscale Model (KAMM) with Risø's WAsP (Wind Atlas Analysis and Application Program) in order to model the wind resource at any given location. Web-site: www.mesoscale.dk.
Partners: Various.
Sponsor/client: Various.
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

Aujeszky's virus
Programme: MET, project no. 1100 006-00, start date 1.1. 1990, cont.
● This project concerns the development and maintenance of a real-time airborne virus spread monitoring and warning system based on an on-line meteorology tower at Kegnæs in the south-western part of Denmark. The virus in question is Aujeszky's virus, for which pigs are the natural host.
Partners: Danske Slagterier; Danish Bacon and Meat Council (subsidiary).
Sponsor/client: The Danish Veterinary and Food Administration (DVFA).
Contact: Torben Mikkelsen, torben.mikkelsen@risoe.dk, tel. +45 4677 5009.

Understanding the role of vehicle emissions in the formation of secondary organic aerosols
Programme: MET, project no. 1100 053-1, start date 1.1. 1999, cont.
● This project is a collaboration with Ford Forschungszentrum Aachen. The main focus is on the development of explicit chemistry modules for describing the production of condensable molecules through atmospheric oxidation of volatile organic compounds. These modules are being compared with two-parameter absorption approaches currently used in atmospheric chemistry modules.
Partners: None.
Sponsor/client: Ford Forschungszentrum Aachen, Germany.
Contact: Rebecca Barthelmie, r.barthelmie@risoe.dk, tel. +45 4677 5020.

ARGOS
Programme: MET, project no. 1130 503-1, start date 1.10. 1999, cont.
● ARGOS 2003 is the name of the Danish support system for decision-making in case of a nuclear accident. The purpose of this project is to apply the Local Scale Model Chain (LSMC) of this support system to 'Danish national scale' (horizontal: 400 km by 400 km, vertical: 2 km).
This has required several enhancements of the original dispersion model, RIMPUFF (Risø Mesoscale Puff Model), including trifurcation, vertical shear rise, etc., as well as coupling to GSF's food chain module.
In 2003 we have focussed on 3-D advection of puffs, long-range dispersion parameterization, detailed interpolation of wind fields from HIRLAM (high resolution limited area model) using LinCom (linearized computation model) and improved modelling of plume rise. Another major activity has been the support to users in the ARGOS consortium (DEMA, Norway, Ireland, Canada et al.). ARGOS 2003 and thus LSMC are used for exercises by the DSSNET (Network of Users and Developers of Decision Support Systems for Off-site Emergency Management).
Partners: Danish Emergency Management Agency (DEMA), Denmark,
Prolog Development Center A/S, Denmark,
Danish Meteorological Institute (DMI), Denmark
GSF National Research Center for Environment and Health (GSF), Germany.
Sponsor/client: Danish Emergency Management Agency, Denmark.
Contact: Søren Thykier-Nielsen, soeren.thykier@risoe.dk, tel. +45 4766 5026.

Dstl coastal effects
Programme: MET, project no. 1100 063-1, start date 1.3. 2000, end 2003.
We have investigated a simple coastal wind model, based on the LinCom (linearized computation) flow model equations for conservation of momentum, mass and heat. The model, LinCom Coast, is intended for the assessment of coastal dispersion and wind resource estimation. LinCom Coast has been evaluated with data from the Shiermonikoog 1979 coastline experiment in Holland.
Partners: Defence Science and Technology Laboratory (Dstl), United Kingdom.
Sponsor/client: Dstl, United Kingdom.
Contact: Torben Mikkelsen, torben.mikkelsen@risoe.dk, tel. +45 4677 5009.

WATERMED
Programme: MET, project no. 1100 066-1, start date 1.2. 2000, end 2003.
● The overall purpose of the WATERMED projects (WATer use Efficiency in natural vegetation and agricultural areas by Remote sensing in the MEDiterranean

basin) was to determine the availability of water in drought-prone areas by means of satellite remote sensing and modelling.
Our main contribution to the project was the calculation of surface momentum and sensible heat flux for a site in Southern France. A microscale aggregation model has been applied to heterogeneous land surfaces in order to estimate areal heat and water vapour flux on the basis of high-resolution satellite remote sensing data. Results were successfully verified by comparing with data from several eddy correlation flux stations in agricultural felds, and aggregation results proved superior to all other methods we tested.
Partners: Universitat de València, Spain,
Institut National de la Recherche Agronomique (INRA), France,
Université Cadi Ayyad, Marrakech, Morocco,
National Authority for Remote Sensing and Space Sciences (NARSS), Egypt.
Sponsor/client: European Commission, Fifth Framework Programme; Confirming the international role of Community research, INCO-Med.
Contact: Charlotte Bay Hasager, charlotte.hasager@risoe.dk, tel. +45 4677 5014.

ENSEMBLE
Programme: MET, project no. 1100 069-1, start date 1.10. 2000, concluded 30.9. 2003.
● EU's ENSEMBLE project addresses the problem of achieving a common, coherent strategy among European national emergency management agencies, when various national, long-range dispersion forecasts differ from one another during an accidental atmospheric release of radioactive material. ENSEMBLE produces new, web-based software tools for real-time reconciliation and harmonisation of dispersion forecasts from meteorological and emergency centres across Europe during an accident. Such tools have been made available to participating national emergency and meteorological forecasting centres for direct integration into operational emergency information systems or future systems development.

This EU Fifth Framework Programme project was ended in 2003 and is documented in Risø-R 1435. The ENSEMBLE project continues in the Sixth Framework Programme as a demonstration as well as an RTD project under the auspices of the EU radiation protection activity for decision support during nuclear emergencies (IP EURANOS).
Partners: German Meteorological Service (DWD), Germany,
Het Koninklijk Nederlands Meteorologisch Instituut (KNMI), Netherlands,
National Institute of Public Health and the Environment (RIWM), Netherlands,
Royal Meteorological Institute of Belgium, Belgium,
Météo-France, France,
Met Office, UK,
Finnish Meteorological Institute, Finland,
Swedish Meteorological and Hydrological Institute, Sweden,
Danish Meteorological Institute, Denmark,
Central Institute of Meteorology and Geodynamics, Austria,
Enviroware srl, Italy,
Institute of Atomic Energy, Poland,
Norwegian Meteorological Institute, Norway,
National Centre for Scientific Research 'Demokritos', Greece,
Joint Research Centre; Institute for Environment and Sustainability, Ispra, Italy,
University of Manchester, England,

U.S. Dept. of Energy; Savannah River Site, USA,
Danish Emergency Management Agency, Denmark.
Sponsor/client: European Commission, Fifth Framework Programme; Research and training in the field of nuclear energy.
Contact: Torben Mikkelsen, torben.mikkelsen@risoe.dk, tel. +45 4677 5009.

DAONEM
Programme: MET, project no. 1100 070-1, start date 1.10. 2000, end June 2004.
● The objective of DAONEM (Data Assimilation for Off-site Nuclear Emergency Management) is to improve the predictive capabilities of the RODOS system (real-time on-line decision support) by developing and implementing data assimilation tools. The Gaussian puff atmospheric dispersion model RIMPUFF is used for the development of a data assimilation capability for the early phase. This model describes the various processes associated with atmospheric dispersion of radioactive material without requiring too much computing time. The relative simplicity of the model should prove an advantage, since the implementation of the Kalman filter would be at least an order of magnitude more difficult in more complex models such as a particle model. The architecture of the original dispersion model will need modifications in order to meet requirements imposed by the data assimilation approach.

In 2003, the project was extended by integrating RIMPUFF with Kalman filtration into the RODOS 5.0 version of the diagnostic LSMC (local scale model chain), and partly into the similar, parallel, but anyway different, prognostic LSMC. Integration of the RIMPUFF/Kalman code continues into the first half of 2004.

The case used for test and further development of the early phase Kalman filtration procedure was 'true' dispersion and gamma radiation as calculated by the National Institute of Public Health and the Environment (RIVM) in the Netherlands – using their dispersion code and based on KNMI-HIRLAM meteorological data fields. This resulted in gamma dose rates for 163 detector positions throughout the Netherlands.

In order to achieve the best possible imitation of an actual release with access to only limited meteorological information, the following LSMC/RIMPUFF/Kalman runs have been based on single point meteorology, an extract from the Dutch HIRLAM meteorological fields for a point close to the chosen point of release, the Borssele power plant.

More tests have been carried out, and the best so far involved a virtual set of 12 detectors encircling the power plant at a 1 km radius. For calculations we used RIMPUFF and Kalman filter in the PV 5.0 version of RODOS.
Partners: Belgian Nuclear Research Centre (SCK/CEN), Belgium,
Forschungszentrum Karlsruhe, Germany
Sponsor/client: European Commission, Fifth Framework Programme; Research and training in the field of nuclear energy.
Contact: Torben Mikkelsen, torben.mikkelsen@risoe.dk, tel. +45 4677 5009.

DSSNET
Programme: MET, project no. 1100 072-1, start date 1.10. 2000, end 31.12. 2004.
● The DSSNET (Network of Users and Developers of Decision Support Systems for Off-site Emergency Management) will establish an effective and accepted framework for better communication and understanding between the operational community and

the many diverse disciplines involved in R&D, in order to make well informed and consistent judgements with respect to practical improvements of emergency response in Europe. DSSNET will establish a close interaction among the users of decision support systems, users of RODOS (Real-time On-line Decision Support) in particular – and the R&D community, in order to improve mutual understanding and to encourage feedback on practical experiences from systems application.
Partners: Forschungszentrum Karlsruhe, Germany,
Danish Emergency Management Agency, Denmark.
Sponsor/client: European Commission, Fifth Framework Programme; Research and training in the field of nuclear energy.
Contact: Torben Mikkelsen, torben.mikkelsen@risoe.dk, tel. +45 4677 5009.

EU SAMEN
Programme: MET, project no. 1100 073-1, start date 1.1. 2001, end August 2004.
- The objectives of the thematic project cluster SAMEN are
- to ensure the efficient and timely exchange of data, information and results among respective EC Fifth Framework Programme radiation protection projects, thus avoiding duplication, maximising synergy and promoting coherence,
- to provide a forum that may review and monitor the progress of each project and advise on the direction of research in the subsequent period,
- to maintain focus on the broader objectives of the programme to which the individual projects are subservient,
- to ensure that each project retains a practical focus (i.e. is undertaken in a manner that will facilitate practical effect),
- to provide better feedback between scientists and potential user communities, and
- to facilitate and promote the timely use of results/developments in practical decision support systems for off-site emergency management and restoration of contaminated environments (particularly in the RODOS system).

Partners: Forschungszentrum Karlsruhe, Germany,
National Radiological Protection Board, United Kingdom,
Belgian Nuclear Research Centre (SCK/CEN), Belgium.
Sponsor/client: European Commission, Fifth Framework Programme; Research and training in the field of nuclear energy.
Contact: Torben Mikkelsen, torben.mikkelsen@risoe.dk, tel. +45 4677 5009.

SOLA review
Programme: MET, project no. 1130 001-1, start date 15.1. 2001.
- This activity encompasses review series of external persons, institutions or research programmes.

Partners: None.
Sponsors: Various – chiefly the European Commission.
Contact: Søren Larsen, soeren.larsen@risoe.dk, tel. +45 4677 5012.

Ar-41 lidar experiment
Programme: MET, project no. 1100 077-1, start date 1.1. 2001, end 2003.
- This was an experimental exercise for the purpose of evaluating the coupled near-range atmospheric dispersion and dose rate module in RIMPUFF (Risø Mesoscale Puff Model), as it is presently used by nuclear emergency decision support systems RODOS and ARGOS NT.

Based on the small, but traceable amount of routinely released Argon-41 from the SCK/CEN research reactor in Mol, Belgium, the vent plume's centreline and dispersion parameters were determined experimentally from lidar scans and simultaneously measured ground radiation fluxes. A database has been compiled with simultaneous measurements of the plume geometry and radiation field based on Argon-41 decay, together with in-situ measurements of meteorological parameters. Subsequently, the joint tracer/radiation experimental data set has been used to evaluate the accuracy of predictions of dispersion parameters and gamma fluence rates obtained by the atmospheric dispersion and dose rate model RimPuff.
Partners: Risø National Laboratory, Radiation Research Department,
Belgian Nuclear Research Centre (SCK/CEN), Belgium,
Danish Emergency Management Agency, Denmark,
Technical University of Denmark.
Sponsor/client: Nordic Nuclear Safety Research; a Nordic co-operation.
Contact: Torben Mikkelsen, torben.mikkelsen@risoe.dk, tel. +45 4677 5009.

3-D extreme loads
Programme: MET, project no. 1100 078-1, start date 1.3. 2001, concluded.
- The objective of this project was to improve the design base for extreme and fatigue loads on wind turbines in flat or mountainous terrain. Main activity was the development of models for non-Gaussian 3-D turbulence fields and extreme gusts or change of direction. In the course of the project, we have developed various techniques, based on Fourier transformation, for the estimation of extreme and fatigue loads. A method for coherent gusts in 3-D turbulence fields seems particularly interesting. For further information, see www.risoe.dk/vea-atu/extreme-fatigue.

Partners: Technical University of Denmark,
initially NEG Micon A/S, as of January 2004; Vestas Wind Systems A/S, Denmark.
Sponsor/client: Danish Energy Authority, Denmark.
Contact: Morten Nielsen, morten.nielsen@risoe.dk, tel. +45 4677 5022.

Earth observation data for up-scaling carbon flux and water budget at Zealand (EO-Flux-Budget)
Programme: MET, project no. 1100 079-1, start date 1.1. 2001, concluded December 2003.
- Measurements of CO_2 emission and deposition on Zealand were collected from five sites representing major Danish biotopes. Such measurements provide valuable information on the temporal variability of ecosystem fluxes and their long-term trends, however the purpose of the EO-Flux-Budget-project has been to combine Earth observation (EO) data and a GIS-based soil/vegetation/atmosphere transfer model (DaisyGIS) for the spatial upscaling of such data from Zealand.
Due to the heterogeneous nature of the landscape, the surface conditions responsible for atmospheric fluxes vary with the scale of modelling. In EO-Flux-Budget, 'effective' (or aggregate) surface variables have been computed directly at the scale of interest, using multiple-resolution EO data, including vegetation quantity and chlorophyll contents which are particularly important when estimating the carbon sinks on Earth. Maps of CO_2 exchange and evapotranspiration rates have been produced and validated in time and space, using tower fluxes and airborne flux measurements.
Partners: University of Copenhagen, Institute of Geography (co-ordinator), Denmark,
Risø National Laboratory, Plant Research Department,

DHI Water & Environment, Denmark,
Royal Veterinary and Agricultural University, Denmark.
Sponsor/client: Danish Technical Research Council (STVF), Denmark, (follow-up to European Space Agency (ESA) project.)
Contact: Charlotte B. Hasager, charlotte.hasager@risoe.dk, tel. +45 4677 5014.

Investigation of Lagrangian properties of turbulence
Programme: MET, project no. 1100 081-1, start date 22.6. 2001, cont.
- A series of new techniques are employed for measuring all terms in the Navier-Stokes equations; only exception is the pressure gradient, as it may be calculated from other terms. This requires measurements of velocity gradients and acceleration on scales of the order of the Kolmogorov scale which may be achieved with three-dimensional particle tracking by four digital cameras. Using an ultra-fast position sensitive diode and a sweeping laser sheet would be another relevant option. The latter part of the project concentrates on measuring the movements of groups of particles.

Partners: None.
Sponsor/client: Danish Technical Research Council (STVF), Denmark.
Contact: Jakob Mann, jakob.mann@risoe.dk, tel. +45 4677 5019.

Investigation of a new bi-static SODAR remote sensing concept for wind profile measurements in connection with large wind turbines
Programme: MET, project no. 1100 082-1, start date 1.8. 2001, cont.
- This project relates to the new generation of large wind turbines; by means of sound, we investigate ground-based remote sensing of the vertical wind speed profile. At high wind speeds and near-neutral stratifications, a bi-static SODAR (sonic detection and ranging) configuration has inherent advantages over the traditional mono-static configurations. We investigate the theoretical potentials for improving the accuracy of bi-static acoustic SODAR systems, using remote sensing of vertical wind profiles.

A single-legged bi-static SODAR instrument has been developed and tested for performance under various meteorological conditions, and inter-compared with the 123 metres tall meteorological tower at Risø. The bi-static SODAR is a potential replacement for met tower-based wind profile measurements at heights between 50 and 150 m.
Partners: University of Salford, Faculty of Science, Engineering & Environment, UK.
Sponsor/client: Danish Technical Research Council (STVF), Denmark,
internal funding.
Contact: Torben Mikkelsen, torben.mikkelsen@risoe.dk, tel. +45 4677 5009.

RS Indlejring (inclusion)
Programme: MET, project no. 1100 086-1, start 1.1. 2001, cont.
- The full title is Remote Sensing Based Crop Simulation and Soil/Vegetation/ Atmosphere Transport Modelling: RS-Model-Indlejring. It is the continuation from 2001 to 2005 of a Danish project originally started in 1996 within the Earth Observation initiative.

The purpose of this project is to study the interactions between *field-* and *landscape-*scale soil/vegetation/atmospheric transport (SVAT) by means of ground-based experimental data combined with information from digital remote sensing images. We focus on surface fluxes of water vapour, heat and CO_2. The water, heat and CO_2

cycles are important to crop simulation which is relevant for efficient land-use planning, crop management and yield predictions.
The overall objective is to get a better understanding of processes ranging from the very fine scale (plant/canopy) over homogeneous fields to landscape mosaics. Previously developed models from five Danish research institutions will be used jointly to pass relevant information from 'point' to 'area' when trying to estimate H_2O and CO_2 cycles.
Partners: the Danish Institute of Agricultural Sciences, Research Centre Foulum,
DHI Water & Environment,
The Royal Veterinary and Agricultural University,
Institute of Geography, University of Copenhagen.
Sponsor/client: Danish Research Councils (SNF, STVF and SJF) and the former Danish Space Board.
Contact: Niels Otto Jensen, n.o.jensen@risoe.dk, tel. +45 4677 5007.

CBRN modelling
Programme: MET, project no. 1100 091-0, start date 1.2. 2002, cont.
- This is a pre-project analysis. The ultimate goal is to establish a decision support system (DSS) for the management of emergencies that involve the release of chemical, biological or nuclear substances to the environment. The DSS-system will apply to short as well as long-distance dispersion of effluents, including dispersion in urban environments.

The actual development of the system is proposed to start late 2004 or January 2005. The system will include dispersion models developed by Risø and its collaborators (urban dispersion, heavy gas, chemicals, virus). A selection of relevant models have been scrutinized, and a budget has been set up. The Argos shell developed by DEMA and Prolog will constitute the framework of the future system.
Partners: Danish Emergency Management Agency (DEMA), Denmark,
Prolog Development Center A/S, Denmark,
Defence Science And Technology Laboratory (Dstl), United Kingdom.
Sponsor/client: Danish Emergency Management Agency, Denmark.
Contact: Søren Thykier-Nielsen, soeren.thykier@risoe.dk, tel. +45 4766 5026.

Mars NetLander
Programme: MET, project no. 1100 092, start 20.4. 2002, cont.
- Danish participation in the European NetLander project which aims to design, equip and ultimately land four surface measuring stations on Mars.

The MET activity includes project coordination and the design of NetLander's atmospheric and surface measurement equipment. The other Danish partners focus on magnetic measurements and the collection of Martian dust. The instruments that are being developed for the NetLander project will also be considered for projects such as NASA's Mars Science Laboratory.
Partners: The overall NetLander project includes participation from 40 groups in Europe and USA. Besides Risø National Laboratory, the Danish NetLander Consortium has participation from
University of Copenhagen; Niels Bohr Institutet for Astronomi, Fysik og Geofysik,
Danish Space Research Institute,
Technical University of Denmark; Ørsted DTU.
Sponsor: European Space Agency (ESA); PRODEX (Programme de Développement d'Experiences Scientifiques).

Contact: Søren E. Larsen, soeren.larsen@risoe.dk, tel. +45 4677 5012.

EMARAD
Programme: MET, project no. 1100 093-1, start date 1.10. 2002, cont.
● The purpose of this NKS (Nordic Nuclear Safety Research) project is to support Emergency MAnagement & RADiation monitoring in nuclear and radiological accidents. The basic aim of the EMARAD project is to establish a web-server-based library containing results from a wide range of consequence calculations, and to create a user interface for the design and test of radiation monitoring strategies. MET's contribution to this Nordic project comprises the design and evaluation of scenarios resulting from the detonation of 'dirty bombs' in urban areas. We calculate radiation doses and surface contamination, and evaluate the effects of various decontamination strategies. The so-called UDM (Urban Dispersion Model), developed by Dstl, UK, is used for calculations. At this point, we have completed a parameter study for dispersion in an artificial city.
Partners: Radiation and Nuclear Safety Authority (STUK), Finland,
VTT Processes, Finland,
Swedish Radiation Protection Authority (SSI), Sweden,
Lund University, Lund, Sweden,
Norwegian Radiation Protection Authority (NRPA), Norway,
Geislavarnir Ríkisins (Icelandic Radiation Protection Institute), Iceland,
Defence Science and Technology Laboratory (Dstl), Physical Sciences Dept., UK.
Sponsor/client: NKS (Nordic Nuclear Safety Research), Denmark *(secretariat)*.
Contact: Søren Thykier-Nielsen, soeren.thykier@risoe.dk, tel. +45 4766 5026, or
Jørn Roed, jorn.roed@risoe.dk, tel. +45 4766 4186.

European Wind Atlas
Programme: MET, project no. 1130 603-1, start date 1.1. 1989, cont.
● Distribution of the European Wind Atlas, published in 1989.
Partners: None.
Sponsor/client: Various.
Contact: Niels G. Mortensen, niels.g.mortensen@risoe.dk, tel. +45 4677 5027.

Wind Atlas Analysis and Application Program (WAsP)
Programme: MET, project no. 1130 600, start date 1.7. 1987, cont.
● The WasP project encompasses the development, implementation and verification of software tools for;
- wind data analysis,
- map editing and digitisation,
- wind atlas generation,
- wind climate estimation,
- prediction of wind power production,
- micro-siting of wind turbines,
- wind farm production calculations,
- wind farm efficiency evaluation, and
- wind climate and wind resource mapping.

The project also includes software support, courses and training.
Partners: None.
Sponsor/client: Various
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

Wind Atlas for the Gulf of Suez
Programme: MET, project no. 1130 603-2, start date 1.1. 1995, cont.
● Distribution of *Wind Atlas for the Gulf of Suez 1991-95* and the associated database.
Partners: None.
Sponsor/client: Various.
Contact: Niels G. Mortensen, niels.g.mortensen@risoe.dk, tel. +45 4677 5027.

Wind atlas for Russia
Programme: MET, project no. 1130 603-3, start date 20.11 1997, cont.
● This project concerns the development of a wind atlas for Russia, based on the Risø wind atlas methodology. We will analyse data from more than 300 stations distributed all over the Russian territory. Each station will be analysed with respect to meteorological data (wind speed and direction), terrain (orography and roughness) and obstacles.
Partners: The Russian-Danish Institute for Energy Efficiency (RDIEE), Moscow, Russia.
Sponsor/client: Danish Energy Authority.
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

Instrumentation of offshore masts
Programme: MET, project no. 1130 103-1, start date 1.8. 1997, cont.
● Two major Danish power supply companies, SEAS and Elkraft, have sponsored our equipment of a number of offshore masts (Gedser Land, Gedser Rev, Rødsand and Omø Stålgrunde) as well as the operation of the meteorological instrumentation that is required in order to provide a database for wind resource assessment.
Partners: None.
Sponsor/client: SEAS, Denmark,
Elkraft, Denmark.
Contact: Rebecca Barthelmie, r.barthelmie@risoe.dk, tel. +45 4677 5020.

WAsP consulting
Programme: MET, project no. 1130 610-1, start date 20.11. 1997, cont.
● Consultancy in connection with wind resource estimation is an important MET activity. Services may include second opinion studies, due diligence, offshore wind farm production estimates and measuring programmes.
Partners: A number of companies and international institutions.
Sponsor/client: Various.
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

Transfer of wind resource know-how to the Czech Republic
Programme: MET, project no. 1105 042-1, start date 1.11. 1999, cont.
● The purpose of this project is to increase the capacity in the Czech Republic to estimate domestic wind resources. A training workshop for about 10 target persons has been established. The project also provides a survey of wind resources in the Czech Republic, clarifying the circumstances and perhaps proposing a solution for a presently less successful wind farm project.
Partners: None.

Sponsor/client: The former Danish Co-operation for Environment and Development (DANCED), now the Danish Foreign Office, Danida.
Contact: Ole Rathmann, ole.rathmann@risoe.dk, tel. +45 4677 5003.

EPRI-Prediktor Texas
Programme: MET, project no. 1105 043-1, start date 1.10. 2000, cont.
- Confidential.

Partners: Confidential.
Sponsor/client: Electric Power Research Institute (EPRI), California, USA,
Dept. of Energy (DOE), USA.
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

Efficient development of offshore wind farms (ENDOW)
Programme: MET, project no. 1105 044-1, start date 1.3. 2000, cont.
- The ENDOW project is co-ordinated at Risø and funded by the European Commission's Fifth Framework Programme. The objectives of the project are to evaluate the performance of a variety of wake models in the offshore environment, to enhance these models and subsequently link them with improved boundary layer models. This will enable a comparison of offshore wake effects with other factors which have an impact on the design and economics of offshore wind farms.

Partners: Uppsala University, Sweden,
Garrad Hassan and Partners Ltd, United Kingdom,
The Robert Gordon University, United Kingdom,
University of Oldenburg, Germany,
SEAS, Denmark,
Elsam A/S, Denmark,
initially NEG Micon A/S, now Vestas Wind Systems A/S, Denmark,
Energy research Centre of the Netherlands (ECN), Netherlands,
Ecofys (subcontractor to ECN), Netherlands.
Sponsor/client: European Commission, Fifth Framework Programme.
Contact: Rebecca Barthelmie, r.barthelmie@risoe.dk, tel. +45 4677 5020.

Baltic wind atlas
Programme: MET, project no. 1105 045-1, start date 1.1. 2000, cont.
- The aim of this project is to establish a wind atlas for relevant regions in the Baltic countries by reviewing and analysing wind measurements already existent, and by establishing new measurements in particularly promising – coastal – areas. Our contribution is mainly consultancy regarding the selection of new measurement sites as well as the purchase and installation of measuring equipment.

Partners: UNDP, Global Environment Facility (GEF) (co-ordinator),
Lars Mach, free-lance consultant, Germany.
Sponsor/client: United Nations Development Programme (UNDP),
United Nations Office for Project Services (UNOPS).
Contact: Ole Rathmann, ole.rathmann@risoe.dk, tel. +45 4677 5003.

Prediktor
Programme: MET, project no. 1130 611-1, start date 1.10. 2000, cont.
- Sales, marketing and implementation of the Zephyr/Prediktor short-term prediction system, developed by MET.

Partners: Various.

Sponsor/client: Various.
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

EPRI Prediktor California
Programme: MET, project no. 1105 047-1, start date 1.10. 2000, cont.
- Confidential.

Partners: Confidential.
Sponsor/client: Electric Power Research Institute (EPRI), California, USA,
California Energy Commission, USA.
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

UNEP/ SWERA global wind atlas
Programme: MET, project no. 1105 048-1, start date 2.3. 2000, cont.
- This project concerns the development of a full-scale project regarding the production of a solar and wind atlas for 10 to 15 countries around the globe: SWERA, Solar and Wind Energy Resource Atlas. The output of current work will be a proposal to UNEP for this full-scale project.

Partners: National Renewable Energy Laboratory (NREL), USA,
The Energy and Resources Institute (TERI), (formerly known as Tata Energy Research Institute), India.
Sponsor/client: United Nations Environmental Programme (UNEP), Global Environment Facility (GEF),
Risø National Laboratory, MET.
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

CDMed
Programme: MET, project no. 1105 050-1, start date 1.3. 2000, end 2003.
- These are scenarios and strategies for the implementation of the Kyoto Protocol's Clean Development Mechanism in the Mediterranean region.

Partners: Observatoire Méditerranéen de l'Energie (OME) (co-ordinator), France,
EC's Joint Research Centre, Institute for Prospective Technological Studies (IPTS), Spain,
Enel, Italy,
New and Renewable Energy Authority (NREA), Egypt.
Sponsor/client: European Commission, Directorate-General for Research.
Contact: Erik Lundtang Petersen, erik.lundtang@risoe.dk, tel. +45 4677 5001.

CleverFarm®
Programme: MET, project no. 1105 051-1, start date 1.4. 2000, concluded 3.9. 2003.
- The CleverFarm® project has developed a fusion of all available information regarding a wind farm: The standard SCADA (supervisory control and data acquisition) information, condition monitoring of the drive train, video camera surveillance, and short-term predictions of power generation and wind speeds. This combination makes it possible to determine the remaining lifetime of components, to schedule maintenance according to needs and to minimize down time. The software is open-sourced and the final report is available as Risø-R-1444 and on www.cleverfarm.com.

Partners: Gram & Juhl, Denmark,
Danish Meteorological Institute, Denmark,
Institut für Solare Energieversorgungstechnik (ISET), Germany,

Renewable Energy Systems Ltd. (RES), United Kingdom,
SEAS, Denmark,
University of Oldenburg, Dept. of Energy and Semiconductor Research (EHF), Germany.
Sponsor/client: European Commission, Fifth Framework Programme; Energy, environment and sustainable development.
Contact: Gregor Giebel, gregor.giebel@risoe.dk, tel. +45 4677 5095.

WEMSAR
Programme: MET, project no. 1105 052-1, start date 1.3. 2000, concluded February 2003.
● Wind energy mapping (WEM) using synthetic aperture radar (SAR). This project concerns the development, validation and demonstration of the potential use of satellite-based SAR, scatterometer and altimeter data combined with meteorological observations for the mapping of wind resources in offshore and near-coastal regions. The sites in question were located in Norway, Denmark and Italy. The Karlsruhe Atmospheric Mesoscale Model (KAMM) has been used for regional scale calculations, whereas WasP was used for local scale calculations.
Partners: Nansen Environmental and Remote Sensing Center, Norway,
NEG Micon A/S, (now Vestas Wind Systems A/S), Denmark,
Terra Orbit AS, Norway,
Italian National Agency for New Technologies, Energy and the Environment (ENEA), Italy.
Sponsor/client: European Commission, Fifth Framework Programme; Energy, environment and sustainable development.
Contact: Charlotte Bay Hasager, charlotte.hasager@risoe.dk, tel. +45 4677 5014.

Improved description of the wind climate in Denmark regarding determination of the wind resource
Programme: MET, project no. 1105 053-1, start date 4.1. 2000, end 2003.
● The Danish Meteorological Institute is developing HIRLAM (HIgh Resolution Limited Area Model) further in order to improve the prediction of wind and weather in general.
MET contributes to this programme by investigating the possibility of using the electricity generation from wind turbines as a measure of wind speed. We use the wind farm model from WasP (Wind Atlas Analysis and Application Program) to derive wind speed information from power generation. The electric transmission utility company Eltra provides the necessary power data.
Partners: Danish Meteorological Institute (DMI), Denmark,
Eltra, Denmark,
Sponsor/client: Danish Energy Authority, EFP 2000 (energy research programme).
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

UVE 2000, calculation of energy production
Programme: MET, project no. 1105 054-1, start date 1.1. 2000, end 2003.
● We are in the process of compiling a database of case studies, including the data and information required for evaluating the accuracy and the reliability of wind power generation estimates based on a variety of approaches and computer models. Case studies are established for a selection of differing wind climatologies and topographical settings. The comparison between predictions and actual power

generation from wind turbines and wind farms serves to evaluate and map the uncertainties involved, and possibly improve our prediction skills.
Partners: Energi- og Miljødata (EMD), Denmark,
Elsam Engineering A/S, Denmark,
WEA Engineering, Denmark, (now dissolved),
initially Bonus Energy A/S, Denmark, as of December 2004: Siemens Power Generation, Germany.
Nordex Energy GmbH, Germany,
Vestas Wind Systems A/S (including the former NEG Micon A/S), Denmark,
DWS-Wincon, Denmark.
Sponsor/client: Danish Energy Authority, UVE (development programme for renewable energy),
WEA Engineering, Denmark, (now dissolved),
initially Bonus Energy A/S, Denmark, as of December 2004: Siemens Power Generation,
Nordex Energy GmbH, Denmark,
Vestas Wind Systems A/S (including the former NEG Micon A/S), Denmark,
DWS-Wincon, Denmark.
Contact: Niels G. Mortensen, niels.g.mortensen@risoe.dk, tel. +45 4677 5027.

UVE, the New WAsP
Programme: MET, project no. 1105 058-1, start date 1.4. 2000, cont.
- The purpose of this project is to develop the next generation flow model in relation to WAsP; Wind Atlas Analysis & Application Program.

Partners: Energi- og Miljødata (EMD), Denmark.
Sponsor/client: Danish Energy Authority; UVE (development programme for renewable energy).
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

EU Med 2010
Programme: MET, project no. 1105 059-1, start date 9.1. 2001, end 2003.
- Large-scale integration of solar and wind power in Mediterranean countries.

Partners: Observatoire Méditerranéen de l'Energie (OME) (co-ordinator), France,
Endesa Cogeneration and Renewables, Spain,
BP Solar, Spain,
Research Centre for Energy, Environment and Technology (CIEMAT), Spain,
Electricité de France (EDF), France,
ARMINES and Ecoles des Mines de Paris, France,
Centro Elettrotecnico Sperimentale Italiano (CESI), Italy,
le Centre de Developpement des Energies Renouvelables (CDER), Morocco,
Société Tunisienne de l'Electricité et du Gaz (STEG), Tunisia,
New and Renewable Enegy Authority (NREA), Egypt,
Electrical Power Resources Survey and Development Administration (EIE), Turkey.
Sponsor/client: European Commission, Fifth Framework Programme; Energy, environment and sustainable development.
Contact: Erik Lundtang Petersen, erik.lundtang@risoe.dk, tel. +45 4677 5001.

Prediktor in Ireland
Programme: MET, project no. 1105060-1, start date 6.2. 2001, concluded.
- Confidential.

Partners: Confidential.
Sponsor/client: Confidential.
Contact: Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

SEAS offshore mast analysis
Programme: MET, project no. 1130 103-1, start date 1.10. 2001, cont.
● Analysis of wind resources at Rødsand, Omø Stålgrunde and Gedser, based on measurements from in situ masts in 1996.
Partners: None.
Sponsor/client: initially SEAS. The activities of SEAS Vind A/S were taken over by Energi E2 in 2003.
Contact: Rebecca Barthelmie, r.barthelmie@risoe.dk, tel. +45 4677 5020.

Wind energy assessment and wind engineering (WindEng)
Programme: MET, project no. 1105 065-1, start date 1.9. 2002, cont.
● Risø is the co-ordinator of this project, concerning a European training network under the auspices of the European Commission's Fifth Framework Programme; Improving human research potential. The purpose of the network is to bring together young and experienced researchers to work jointly on defining the basis for the design of wind turbines and wind farms in different environments.
This includes:
• The definition of reliable values for turbulence descriptors to be used for modelling turbulent wind fields (i.e. turbulence intensity, spectra, coherence, shear etc.) in homogeneous, complex terrain and offshore. These values and descriptors will be included in guidelines for wind turbine design.
• Improving current methods for modelling wind climates throughout Europe in order to provide reliable tools for calculating the energy generation from wind farms in complex terrain and offshore.
The network will address all European climates from the cold Scandinavian to the Mediterranean regions. We will also offer guidelines for optimum turbine design and siting procedures for isolated generators or turbine parks.
Young scientists will participate in national and international research programmes and research strategies. The exchange of experience and personal contacts among the academic and research institutions and private companies involved is expected to yield improved design criteria for our end-users.
Partners: Risø National Laboratory (co-ordinator), Denmark,
University of Oldenburg, Germany,
German Wind Energy Insititute, (DEWI), Germany,
initially NEG Micon, now Vestas Wind Systems A/S, Denmark,
Centre for Renewable Energy Sources, CRES, Greece,
the former SEAS Vind A/S, now Energi E2, Denmark,
Istituto di Fisica dell'Atmosfera, (IFA), Italy,
Finnish Meteorological Institute (FMI), Finland.
Sponsor/client: European Commission, Fifth Framework Programme.
Contact: Anna Maria Sempreviva, anna.sempreviva@risoe.dk, tel. +45 4677 5025,
Lars Landberg, lars.landberg@risoe.dk, tel. +45 4677 5024.

EU Anemos
Programme: MET, project no. 1105 066-1, start date 1.10. 2002, cont.

● This project is aimed at the development of advanced forecasting models that will substantially outperform current methods. The new prediction models are to be implemented in a software platform and installed for online operation at on- and offshore wind farms by the end-users participating in the project.
Research on physical models emphasizes the need for techniques for use in complex terrain and the development of prediction tools based on CFD (computational fluid dynamics), meso- and microscale models. Statistical models are developed for the downscaling of predictions, power curve representation and for upscaling in relation to with predictions at a regional or national level.
A benchmarking process that includes a number of case studies will be employed in order to evaluate the performance of the new models and to compare them with current models.
A next-generation forecasting software, Anemos, is being developed for the integration of the various models. This software will be installed for online operation at a number of on- and offshore wind farms. Finally, the benefits from wind prediction will be evaluated during online operation, and we will produce guidelines for the optimal use of wind forecasting systems.
Partners: A total of 22 partners from seven European countries, co-ordinated by Armines, France.
Sponsor/client: European Commission, Fifth Framework Programme: Energy, environment and sustainable development.
Contact: Gregor Giebel, gregor.giebel@risoe.dk, tel. +45 4677 5095.

PSO Ensemble
Programme: MET, project no. 1105 068-1, start date 1.6. 2002, cont.
● New challenges such as the push for more offshore wind parks and an increasing wind energy penetration in public power supply call for even better wind forecasts. In the current prediction system we have identified three major points for improvement:
• a measure for the expected uncertainty of any given prediction,
• longer forecast horizons, and
• better forecasts.
This project will tackle these issues mainly by using additional numerical weather models, particularly ensemble forecasts. Ensembles consist of a multitude of possible results, all of which are considered equally probable. They may therefore be used to increase the knowledge of future weather conditions, and to assess the uncertainty of the actual forecast.
A meaningful representation of the uncertainty is a focal point in this work. A measure of uncertainty along with long-term forecasts may prove useful for power plant activity planning or electricity trading by the utilities. Preliminary results show that the ensemble from the European Centre for Medium-Range Weather Forecasts (ECMWF) contains information on uncertainty which needs to be transformed with a newly developed technique – into operational fractiles of the forecast.
Partners: Technical University of Denmark (DTU), dept. of Informatics and Mathematical Modelling,
Danish Meteorological Institute, Denmark,
Elsam A/S, Denmark,
Energi E2 A/S, Denmark,
the former SEAS Vind A/S, now Energi E2 A/S, Denmark.
Sponsor/client: Elkraft System, under the PSO act (public service obligation).
Contact: Gregor Giebel, gregor.giebel@risoe.dk, tel. +45 4677 5095.

CBHA review
Programme: MET, project no. 1130 001-2, start date 1.1. 2003, cont.
This activity involves reviewing in relation to EU's framework programme and expert meetings in ESA GMES (Global Monitoring Environment and Security) policy groups.
Partners: None.
Sponsor/client: European Commission,
European Space Agency (ESA).
Contact: Charlotte Bay Hasager, charlotte.hasager@risoe.dk, tel. +45 4677 5014.

Computational methods in wind power meteorology
Programme: MET, project no. 1130 101-1, start date 1.1. 2003, cont.
- The calculation of atmospheric flow over complex terrain is extremely difficult. With this project we aim to accurately resolve the mean wind and unsteady wind fields on very fine scales in order to achieve high accuracy in the lower part of the atmosphere.

Increased spatial resolution will involve several scientific challenges due to the interaction between the lower part of the atmospheric boundary layer and detailed features of a complex terrain. Sophisticated turbulence closure schemes are needed in order to model the separating flow behind ridges, escarpments and steep hills, and to capture streamline curvature adequately. Furthermore, thermal stability effects often have a significant impact on flow. These features are absent in current simple linear micro-siting models such as WAsP. To establish the capability of increased spatial resolution we use the CFD code EllipSys3D which has been developed jointly by Risø's Wind Energy Department and the Technical University of Denmark (DTU). The model is further developed into an atmospheric model.
Partners: None.
Sponsor/client: Danish Technical Research Council (STVF).
Contact: Jakob Mann, jakob.mann@risoe.dk, tel. +45 4677 5019,
Bo Hoffmann Jørgensen, bo.hoffmann@risoe.dk, tel. +45 4677 5471.

EO Windfarm
Programme: MET, project no. 1130 106-1, start date 1.12. 2003.
- Earth observation-based information service for wind farm management is a development project. Software and service developed by the partners is meant to serve wind engineers in various aspects.

The digital elevation model (DEM) from the Shuttle Radar Topography Mission data, land roughness through satellite-based land cover mapping and offshore wind resource estimation based on synthetic aperture radar (SAR), scatterometer and altimeter wind observations are all validated in the course of the project, and relevant software is developed for engineering applications.
Partners: Nansen Environmental and Remote Sensing Center, Norway,
Vestas Wind Systems A/S, Denmark,
Elsam Engineering A/S, Denmark,
ADEME (the French Agency for Environment and Energy Management), France,
ARMINES (Association pour la Recherche et le Développement des Méthodes et Processus Industriels), France,
ARGOSS (Advisory and Research Group on Geo Observation Systems and Services), Netherlands,

Airtricity, Ireland.
Sponsor/client: European Space Agency (ESA), Earth Observation Market Development.
Contact: Charlotte Bay Hasager, charlotte.hasager@risoe.dk, tel. +45 4677 5014.

SAR Wake
Programme: MET, project no. 1130 301-1, start date 1.2. 2003.
- This is an offshore wake effect study based on Earth Observation synthetic aperture radar.

A series of satellite images from the ERS-2 (European Remote-Sensing Satellite 2) and Envisat ASAR (advanced synthetic aperture radar) are used to quantify the spatial extend of the wake behind the Horns Rev wind farm located in the Norh Sea. Furthermore, an airborne experimental campaign with the German ESAR (enhanced SAR) from the German Aerospace Center DLR has been used for recording the wake in high spatial resolution and in various bands (C- and L-band) and polarization VV (vertical transmit/receive) and HH (horizontal transmit/receive). The data we have acquired from wake observations are compared with results from state-of-the-art wake models.
Partners: Elsam Engineering A/S, Denmark,
Technical University of Denmark, Ørsted-DTU, Denmark.
Sponsor/client: the Danish Technical Research Council (STVF).
Contact: Charlotte Bay Hasager, charlotte.hasager@risoe.dk, tel. +45 4677 5014.

Nordic centre for studies of ecosystem carbon exchange and its interactions with the climate system (NECC)
Programme: MET, project no. 1130 302-1, start date 1.1. 2003, cont.
- The participants in this collaboration examine the influence of the ecosystem's varying carbon and methane contents on the greenhouse effect and the climate.

Large amounts of organic carbon are stored in the Nordic forests, lakes and wetlands. It is feared that climate changes may cause a decrease in these carbon sinks or turn them into sources of greenhouse gases.
We examine the carbon cycles by measuring fluxes of carbon dioxide and methane at 26 eddy correlation sites operated by NECC. The various groups within the centre also employ mobile systems for short-term measurements and an aircraft for studies of local carbon dioxide fluxes. The objective of the centre is to create a common database that will facilitate the analysis and synthesis of the collected data.
Partners: The project includes partners from Danish, Finnish, Icelandic and Swedish institutes, and it is coordinated from Lund University.
Sponsor/client: The Nordic Council of Ministers.
Contact: Niels Otto Jensen, n.o.jensen@risoe.dk, tel. +45 4677 5007.

Research centre on Biosphere-Aerosol-Cloud-Climate Interactions (BACCI)
Programme: MET, project no. 1130 303-1, start date 1.1. 2003, cont.
The centre examines various interactions between the atmosphere and the Earth's surface biosphere, and their linkage with climate change. Notably interactions and processes involving aerosols and aerosol formation are considered. We are primarily concerned with exchanges that take place between the surface and the atmosphere.
In collaboration with another, similar research centre, NECC, BACCI is in charge of a training programme, called CBACCI, for students and scientists.

Partners: This project includes partners from all the Nordic countries, and it is coordinated from the University of Helsinki.
Sponsor: The Nordic Council of Ministers
Contact: Søren E. Larsen, soeren.larsen@risoe.dk, tel.+45 4677 5012.

CupSea
Programme: MET, project no. 1130 306-1, start date 1.1. 2003, end 1.2. 2004.
- The objective of this project is to study the air/sea exchange of atmospheric CO_2 in the Greenland Sea Basin, and to design an air/sea model that takes atmospheric forcing as well as biological uptake into account. A field experiment, during which the air/sea exchange was measured by means of various micrometeorological methods and the delta-pCO_2 technique, was carried out in October 2003. A one-dimensional marine model has been developed and validated from the data obtained in the experiment, and an air/sea exchange sub-model is under development. The project web site is located at http://www.risoe.dk/vea/projects/cupsea/.

Partners: the National Environmental Research Institute (DMU), Denmark.
Sponsor/client: the Danish Environmental Protection Agency (Miljøstyrelsen), AMAP programme .
Contact: Lotte Sørensen, lotte.geern@risoe.dk , tel. +45 4677 5015.

CarboEuroFlux
Programme: MET, project no. 1130 307-1, start date 1.1. 1996, cont.
- The main task of this project is to carry out long-term eddy correlation measurements of CO_2 and water vapour fluxes over European forests and other ecosystems. The main objectives are

• to provide useful parameters for global and regional scale modellers,
• to analyse the variables that determine energy partitioning by forests and other ecosystems in different climatic zones, and finally
• to determine the sink strength for carbon in these systems as well as the factors governing gains and losses – including differing composition of vegetation in various climatic zones.

A specific Risø interest is the development of an improved soil/vegetation/atmosphere transfer (SVAT) model, and to understand the significant variation in the CO_2 uptake (more than a factor of three for the beech forest in Sorø). The project is linked to the global FluxNet: http://daac.ornl.gov/FLUXNET/.
Partners: Università della Tuscia, Dept. of Forest Environment and Resources (project co-ordinator), Italy,
and about 67 other research institutes from EU countries.
Sponsor/client: European Commission, Directorate-General for Research, Fifth Framework Programme.
Contact: Niels Otto Jensen, n.o.jensen@risoe.dk, tel. +45 4677 5007.

Aeroelastic Design, AED

Research programme
Head of Programme: Flemming Rasmussen

The objective of this research programme is to develop new knowledge and models in aerodynamics, structural dynamics, aeroelasticity, and design loads for application in the design and optimization process of present-day and future wind turbine concepts. Mid-term goals are to develop the following;

- An analytical and numerical tool – 'the numerical wind tunnel' – for aeroelastic design and optimization of wind turbines as well as an experimental wind tunnel facility for verification.
- An aeroelastic design tool capable of simulating detailed response and stability of flexible MW-size wind turbines with control.
- A design complex for the development of current as well as new wind turbine concepts.

The means to reach these goals are long-term strategic and applied research and development in the fields of experimental and numerical aerodynamics as well as aeroacoustics (computational fluid dynamics; CFD, and computational aeroacoustics; CAA), structural dynamics, areoelasticity, stability and design basis.

AED projects

Database on wind characteristics
Programme: AED, project no. 1110 024-01, start date 1.1. 1999, cont.
● The purpose of this project is to provide wind turbine designers and others with a source of reliable, actual wind field time series from a wide range of wind climates and terrain types all over the world. All data are presented in a common format. Organizing the databank comprises the following activities:
• maintaining the database in order to ensure that data as well as hardware and software will be online and available at all times,
• extending the databank with meteorological data from countries outside Europe and from sites and wind climates that are not already well represented,
• broadening database search and analysis facilities, and
• communicating the contents of the databank and the possibilities for use of the data material.
The database is located at http://www.winddata.com.
Partners: Governmental institutions in USA, Japan, Norway, Sweden and the Netherlands.
Sponsor/client: International Energy Agency (IEA); Implementing Agreement on Wind Turbines, Annex XVII.
Contact: Gunner Larsen, gunner.larsen@risoe.dk, tel. +45 4677 5056.

Gearbox loadings and wind turbine dynamics
Programme: AED, project no. 1110 029-00, start date 28.12. 2000, end 31. 12 2003.
● Design loads for wind turbine gearboxes are usually established on the assumption that only static external loads will be applied. The objective of this project is to

investigate the significance of the gearbox as an integrated part of the wind turbine's dynamic system and to clarify the importance of inertia loads due to gearbox accelerations. A detailed structural modelling of the gearbox in a nacelle has been carried out with MSC.Adams software. Simultaneously, measurements were carried out on a real wind turbine in order to identify external loads on the gearbox. Results serve as recommendations for inclusion of inertia loads in gearbox design.
Partners: NEG Micon A/S, Denmark.
Sponsor/client: Danish Energy Authority.
Contact: Kenneth Thomsen, kenneth.thomsen@risoe.dk, tel. +45 4677 5052.

Model rotor experiments under controlled conditions (MEXICO)
Programme: AED, project no. 1110 030-00, start date 1.1. 2001, end 31.12. 2005.
● The main objective of the MEXICO project is to significantly reduce the uncertainty of design calculations by providing an experimental database, obtained by measurements from a 5 m diameter model rotor of a wind turbine, running under the controlled conditions of a wind tunnel. There will be detailed pressure measurements on one blade of the model rotor, combined with flow field measurements and flow visualization. The insight gained from these experiments will be used to improve and validate design tools.
Partners: National Aerospace Laboratory (NLR), Netherlands,
Delft University of Technology (TUD), Netherlands,
Polymarin, Netherlands,
Technion – Israel Institute of Technology,
Technical University of Denmark (DTU),
The Swedish Defence Research Agency (FOI), Division of Aeronautics FFA, Sweden,
Centre for Renewable Energy Sources (CRES), Greece,
National Technical University of Athens (NTUA), Greece.
Sponsor/client: European Commission.
Contact: Helge Aagaard Madsen, helge.aagaard.madsen@risoe.dk, tel. +45 4677 5047.

Wind turbine rotor blades for enhanced aeroelastic stability and fatigue life using passively damped composites (DAMPBLADE)
Programme: AED, project no. 1110 031-00, start date 30.1. 2001.
● This project deals with the design, manufacture and testing of passively damped composite wind turbine blades. The purpose is to reduce vibrations by high structural damping of the blades and thereby increase the lifetime of modern wind turbines. The project consists of various tasks:
• Analytic and experimental investigations of the structural damping mechanisms of composites,
• development of theoretical models for predicting the effect of increased structural damping on turbine response and stability,
• design and manufacture of blades with desired properties, and finally
• a large-scale field test of performance.
Partners: Centre for Renewable Energy Sources (CRES), Greece,
Energy research Centre of the Netherlands (ECN), Netherlands,
Foundation for Research and Technology – Hellas (FORTH), Institute of Chemical Engineering and High Temperature Chemical Processes, Greece,
University of Patras, Greece,

Polymarin, Netherlands (withdrawn from the project in 2003),
Geobiologiki S.A, Greece,
Technical University of Denmark, Dept. of Mechanical Engineering.
Sponsor/client: European Commission.
Contact: Morten Hansen, morten.hansen@risoe.dk, tel. +45 4677 5077.

Wind turbine blade aerodynamics and aeroelastics (Knowblade)
Programme: AED, project no. 1110 033-00, start date 1.12. 2001, end 30.11. 2004.
● The objective of this project is to fill in important knowledge gaps in the wind turbine community by applying Navier-Stokes solvers to a series of unsolved problems. We plan to
• improve power prediction by including laminar/turbulent transition models and advanced turbulence models in Navier-Stokes (NS) solvers,
• develop and implement models for aerodynamic accessories in the wind turbine industry in existing NS-solvers,
• extend present-day NS aeroelastic tools to full 3-D blade configurations, and also investigate the aerodynamic damping properties of 2-D aerofoils with various aerodynamic accessories, and
• investigate industrial flow details such as different tip-shapes and loads during standstill.
Altogether this will upgrade the competence of the European wind turbine industry as regards blade design.
Partners: Foundation for Research and Technology (FORTH), Institute of Applied and Computational Mathematics, Greece,
Vrije Universiteit Brussel, Faculty of Applied Sciences, Belgium,
German Aerospace Centre, Institute of Aerodynamics and Flow Technology, Germany,
LM Glasfiber A/S, Denmark,
Swedish Defence Research Agency (FOI), Dept. of Computational Physics, Sweden,
Technical University of Denmark (DTU), Dept. of Mechanical Engineering,
Centre for Renewable Energy Sources (CRES), Div. of Renewable Energy Sources, Greece,
National Technical University of Athens (NTUA), Faculty of Mechanical Engineering, Greece.
Sponsor/client: European Commission.
Contact: Niels N. Sørensen, niels.soerensen@risoe.dk, tel. +45 4677 5053.

Application, demonstration and further development of advanced aerodynamic and aeroelastic models
Programme: AED, project no. 1110 036-00, start date 1.7. 2002, end 31.12. 2003.
● This project runs for 18 months and is based on a previous five-year research programme on aeroelasticity.
The latest computer models in aerodynamics and aeroelasticity (referred to as the design complex) are used to analyse three MW-size turbines simultaneously. Subsequently, Risø and the Technical University of Denmark (DTU) in cooperation with the manufacturers will estimate how the resulting analysis may affect turbine design. Design improvements based on the new design complex will be identified for later implementation by manufacturers. During design analysis there will be an exchange of knowledge between Risø/DTU and the manufacturers to the benefit of ongoing development of the design complex.

Partners: Technical University of Denmark (DTU),
Bonus Energy A/S, Denmark,
LM Glasfiber A/S, Denmark,
NEG Micon A/S, Denmark,
Vestas Wind Systems A/S, Denmark.
Sponsor/client: Danish Energy Authority.
Contact: Christian Bak, christian.bak@risoe.dk, tel. +45 4677 5091.

HAWC II
Programme: AED, project no. 1110 037-01, start date 1.1. 2003, end date 31.12. 2004.
● This project concerns the development of a new aeroelastic model for the prediction of wind turbine response. This is an entirely new structural model which enables a higher degree of flexibility in the structural modelling of wind turbine structures. Our main objective is to develop an aeroelastic model that may constitute the basis for future design of large offshore wind turbines.
Partner: None.
Sponsor/client: None.
Contact: Kenneth Thomsen, kenneth.thomsen@risoe.dk, tel. +45 4677 5060.

CFD basis
Programme: AED, project no. 1110 037-02, start date 1.1. 2003, end 31.12. 2004.
● This project concerns the further development and maintenance of the Navier-Stokes solver EllipSys2-D/3-D, which was developed in a collaboration between the Dept. of Mechanical Engineering at the Technical University of Denmark and the Wind Energy Dept. at Risø National Laboratory. Some key areas are the development of a 3-D transition prediction model, fully coupled 3-D aeroelastic simulations and 3-D grid generation.
Partner: Technical University of Denmark.
Sponsor/client: None.
Contact: Niels N. Sørensen, niels.soerensen@risoe.dk, tel. +45 4677 5053.

Aeroelastic stability and control of large wind turbines (STABCON)
Programme: VEA, project no. 1110 038-00, start date 1.11. 2002, cont.
● This project deals with the development and verification of advanced aeroelastic stability tools, including the wind turbine control system. These tools are to be applied to the analysis and design of large wind turbines throughout the European wind turbine industry. We explore new ideas and potential for the application of active aeroelastic controls, not only in order to maintain or enhance power but also to increase damping and control/reduce loads on vital components. Today's multi-megawatt wind turbines represent an increased risk of aeroelastic instability as designs are stretched to the limit. The answer to this problem is to increase the reliability of design methods and tools, and to address stability problems specifically as an integrated part of the design process.
Partners: Energy research Centre of The Netherlands (ECN),
Centre for Renewable Energy Sources (CRES), Greece,
National Technical University of Athens (NTUA), Greece,
Technical University of Denmark (DTU),
Universität Stuttgart, Germany,
Delft University of Technology, Netherlands,
NEG Micon A/S, Denmark.

Sponsor/client: European Commission.
Contact: Peter Fuglsang, peter fuglsang@risoe.dk, tel. +45 4677 5071.

Aeroelastically integrated wind turbine control
Programme: AED, project no. 1110 039-00, start date 1.1. 2003, end 31.12. 2004.
● The main objective of this project is the integration of controls into the general design process of wind turbines, as is already the case with structural dynamics and aerodynamics. We particularly focus on pitch-controlled turbines with variable speed. The potential of future controllers will be identified and design limits mapped. This includes the individual pitching of blades based on load response input parameters – in order to optimize operation, reduce loads and enhance stability.
The project is based on a traditional pitch-controlled wind turbine with variable speed. By means of linear as well as non-linear aeroelastic methods, general design tools for controller design will be developed. These design tools will be verified by traditional methods, and optimum controller strategies will be developed. An important aspect of this is the identification of necessary changes in the structural and aerodynamic design in order to obtain an optimum regulator.
The design of controller strategies will address the following issues:
• Optimizing power production while simultaneously reducing the load on main components (gearbox, tower, blades).
• Adaptation of control according to actual operational conditions.
Partners: Technical University of Denmark, Informatics and Mathematical Modelling (IMM) and Dept. of Mechanical Engineering,
Risø National Laboratory, VES, Wind Energy Dept.
Sponsor/client: Danish Energy Authority.
Contact: Morten H. Hansen, morten.hansen@risoe.dk, tel. +45 4677 5077.

Adaptive wing geometry for reduction of wind turbine loads
Programme: AED, project no. 1110 043-00, start date 1.10. 2003.
● The purpose of this project is to reduce the loads caused by turbulence, wind shear etc., on wind turbines. One method being investigated is to use a soft and flexible material for the trailing edge of the blade, thus allowing it to move with the wind. Changing the shape will change the blade forces and ultimately steady the blade deflection in spite of fluctuating winds. 2-D and 3-D aeroelastic analyses will reveal the potential, whereas the trailing edge shape will be designed by means of 2-D computational fluid dynamics (CFD). We intend to use optimization to find an actuator mechanism, and a materials study will suggest the preferable choice of material. Ultimately, we will produce a prototype 2-D aerofoil model and put it to the test in a wind tunnel.
Partners: Technical University of Denmark.
Sponsor/client: Danish Research Agency.
Contact: Thomas Buhl, thomas.buhl@risoe.dk, tel. +45 4677 5467.

Various commercial tasks
Programme: AED, project no. 1110 400-00, start date 20.11. 1997, cont.
● This activity represents a variety of commercial projects, requested primarily by the wind turbine industry. They are small- and large-scale projects in line with research activities. These projects serve three objectives:
• They represent a dedicated investigation,
• they act as an efficient way of transferring new knowledge to industry, and

• they render direct and valuable feedback and inspiration for future research.
Partners: Manufacturers in the Danish wind turbine industry.
Sponsor/client: Manufacturers in the Danish wind turbine industry.
Contact: Flemming Rasmussen, flemming.rasmussen@risoe.dk, tel. +45 4677 5048.

Wind Turbines, VIM

Research programme
Head of Programme: Peter Hjuler Jensen

The purpose of this research programme is to develop and improve current methods for wind turbine loading and safety design, to develop new design methods for structural design and to identify new technical and economic applications.
Mid-term goals are
● Loading and safety: to establish a more rational and empirical basis for a reliable and economic design of wind turbines with models based on a probability theory.
● Structural design: to develop more fundamental structural design modelling of e.g. wind turbine blades and optimal structural design of wind turbine components, as well as new test methods for blades.
● Wind power implementation: to develop methods for the verification of technical as well as economic risks in relation to wind turbines.

VIM projects

Consulting
Programme: VIM, project no. 1120 006, start date 19.11. 1997, cont.
● The VIM programme renders consultancy services to wind turbine manufacturers and power systems operators.
Partners: None.
Sponsor/client: Various.
Contact: Sten Frandsen, sten.frandsen@risoe.dk, tel. +45 4677 5072.

Response simulations for offshore wind turbines
Programme: VIM and AED, project no. 1120 006-13, start date 12.1. 2002, end 31.1. 2003.
● This project is confidential.
Partners: None.
Sponsor/client: Confidential.
Contact: Niels Jacob Tarp-Johansen, niels.jacob.tarp-johansen@risoe.dk, tel. +45 4677 5078.

Operation and maintenance economics of wind turbines
Programme: VIM, project no. 1120 105-00, start date 1.1. 1998, end 31.1. 2003.
● The purpose of this project has been
• to update data and statistics regarding the establishment, operation and maintenance costs of wind turbines, the 500-750 kW generation in particular,
• to highlight questions regarding the technical as well as the economic lifetime of wind turbines based on data regarding operation and maintenance costs,
• to disseminate results in Denmark as well as internationally.
Partners: Danish Wind Industry Association, Denmark,
Elsam A/S, Denmark,

Elkraft, Denmark,
the Danish wind turbine owners' association (Danmarks Vindmølleforening).
Sponsor/client: Danish Energy Authority.
Contact: Peter Hjuler Jensen, peter.hjuler@risoe.dk, tel. +45 4677 5037.

Guidelines for design of wind turbines
Programme: VIM, project no. 1120 110-10, start date 1.1. 1999, cont.
- This project was initiated in order to compile the knowledge of wind turbine design accumulated over the last couple of decades and present it in a clear and easily accessible publication. The publication is produced in a co-operation between Risø National Laboratory and Det Norske Veritas (DNV). An outline of current design requirements to be met by new wind turbines in order to obtain type approval, plays an important role in the guidelines.

Partners: Det Norske Veritas (DNV), Norway.
Sponsor/client: Danish Energy Authority.
Contact: Thomas Krogh, thomas.krogh@risoe.dk, tel. +45 4677 5062, and
Jesper H. Schaarup, jesper.schaarup@risoe.dk, tel. +45 4677 5065.

Certification of wind turbines
Programme: VIM, project no. 1120 120-00, start date 16.1. 2000, cont.
- Det Norske Veritas (DNV) co-operates with Risø in the certification of wind turbines. This co-operation covers all the relevant technological aspects of design verification of wind turbines.

Partners: Det Norske Veritas (DNV), Denmark
Sponsor/client: Wind turbine manufacturers.
Contact: Erik R. Jørgensen, erik.e.joergensen@risoe.dk, tel. +45 4677 5064.

Fatigue strength and life of wind turbine components
Programme: VIM, project no. 1120 124-00, start date 1.5. 2000, end 1.10. 2003.
- The aim of this project is to develop probabilistic tools for the assessment of fatigue strength and service lifetime of components in large wind turbines. Such tools will facilitate the evaluation of uncertainties related to computations of service lifetimes: computations that are indispensable when estimating the economic risk associated with offshore wind turbines.

Partners: Elsam Engineering A/S, Denmark,
a number of Danish wind turbine manufacturers, Denmark,
Risø National Laboratory, Materials Research Department, Denmark.
Sponsor/client: Eltra, Denmark.
Contact: Niels Jacob Tarp-Johansen, niels.jacob.tarp-johansen@risoe.dk, tel. +45 4677 5078.

Environmentally sound design and recycling of wind turbines
Programme: VIM, project no. 1120 127-00, start date 20.12. 2000, end 31.6 2003.
- The objective of this project was to develop methodologies for assessment studies of the life cycle of future wind turbines. This includes the use of methods for technology forecast.

Recommendations for environmentally sound design and recycling methods have been developed and reported.
*Partner*s: Elsam Engineering A/S, Denmark,
LM Glasfiber A/S, Denmark,

Vestas Wind Systems A/S
Risø National Laboratory, Systems Analysis Department, Denmark.
Sponsor/client: Danish Energy Authority.
Contact: Peter Hjuler Jensen, peter.hjuler@risoe.dk, tel. +45 4677 5037.

Recommendations for design of offshore wind turbines (RECOFF)
Programme: VIM, project no. 1120 129-00, start date 24.1. 2001, end 1.9. 2004.
- The objective of this project is to prepare guidelines and recommendations for the design of offshore wind turbines. These guidelines and recommendations are to serve primarily as a basis for further development of European and national standards and certification requirements for offshore wind turbines.

The project also aims to undertake the preparatory work required for establishing a design standard. Current knowledge will be reviewed and supplied with new applied research where necessary. Results may be used directly by manufacturers and consultants in the design process, and they may influence the contents of future tenders for offshore wind energy projects. The RECOFF project relates to the Danish project 'Combination of external loads'.
Partners: Garrad Hassan & Partners Ltd, England,
Germanischer Lloyd AG, Germany,
Energy research Centre of the Netherlands, Netherlands,
Centre for Renewable Energy Sources (CRES), Greece.
Sponsor/client: EU.
Contact: Sten Frandsen, sten.frandsen@risoe.dk, tel. +45 4677 5072.

Improved design rules for large wind turbine blades
Programme: VIM, project no. 1120 130-00, start date 13.3. 2001, end 28.2. 2003.
- The focal point of this project is the development of more rational design methods for large wind turbine blades, based on materials research and development, structural analysis and a series of experiments.

Partners: Risø National Laboratory, Materials Research Department, Denmark,
Technical University of Denmark,
Aalborg University, Denmark,
LM Glasfiber A/S, Denmark,
Vestas Wind Systems A/S, Denmark.
Sponsor/client: Danish Energy Authority, energy research programme (EFP).
Contact: Kim Branner, kim.branner@risoe.dk, tel. +45 4677 5470.

Optimized and uniform safety and reliability of offshore wind turbines
Programme: VIM, project no. 1120 132-00, start date 29.5.2001, end 2004.
- This project has produced a survey of the dependence of the overall safety of wind turbines against structural failure on the turbines' structural safety as well as the reliability of their control and safety systems.

Partners: Risø National Laboratory, Systems Analysis Department, Denmark,
Det Norske Veritas (DNV), Norway,
Energy research Centre of the Netherlands (ECN), Netherlands,
Aalborg University, Denmark.
Sponsor/client: Elkraft, Denmark.
Contact: Niels Jacob Tarp-Johansen, niels.jacob.tarp-johansen@risoe.dk, tel. +45 4677 5078.

Combination of external loads on wind turbine structures
Programme: VIM, project no. 1120 133-00, start date 21.6. 2001, end 30.6. 2003.
● With the growing size of offshore projects, wave and ice loads become increasingly important as compared to wind loads. Thus, the optimal design of offshore turbines relies heavily on optimal design regulations, i.e. on a minute specification of the combined external loads. This project surveys the environmental loads on offshore turbines situated in the Danish seas. We particularly emphasize the concerted action of loads and safety levels. This project complements the European RECOFF project.
Partners: SEAS Distribution A.m.b.A., Denmark,
Carl Bro, Denmark,
DHI Water and Environment, Denmark,
Tech-wise A/S (now: Elsam Engineering A/S), Denmark.
Sponsor/client: Eltra, public service obligation (PSO), Denmark.
Contact: Sten Frandsen, sten.frandsen@risoe.dk, tel. +45 4677 5072.

Fundamentals for remote condition monitoring of wind turbine blades
Programme: VIM, project no. 1120 134-00, start date 25.6. 2001, end 31.3. 2003.
● In the future, majore wind turbines are most likely to be found in large offshore wind farms and will therefore be relatively inaccessible. Consequently, there will be a need for remote on-shore monitoring of blade integrity.
In this project the potential of various sensors has been investigated with regard to the assessment of initiation and extension of structural blade damage.
Partners: Risø National Laboratory, Materials Research Department, Denmark,
FORCE Technology, Denmark,
InnospeXion ApS, Denmark,
LM Glasfiber A/S, Denmark.
Sponsor/client: Public service obligation (PSO), Denmark.
Contact: Peter Hjuler Jensen, peter.hjuler@risoe.dk, tel. +45 4677 5037.

PSO large wind farms
Programme: VIM, project no. 1120 137-00, start date 1.10. 2003, end 30.6. 2004.
● This project was initiated in order to conduct a review of state-of-the-art wake and boundary layer models. Predictions regarding the distance of wind recovery in the vicinity of large offshore wind farms range between 2 and 14 kilometres for typical turbine hub heights. Such predictions may be used to estimate the optimal spacing in terms of neighbouring wind farms.
In order to model the link between wakes and the boundary layer, the new 'Storpark Analytical Model' has been developed and evaluated. As is often necessary in the case of offshore wind farms, the model handles a regular array geometry with straight rows of wind turbines and equidistant spacing between rows.
Firstly, a case of flow direction parallel to the rows in a rectangular geometry is considered by defining three flow regimes: before wakes impact the wind flow, before wakes interact laterally, and finally a multiple wake situation.
Secondly, when the wind flow is not in line with the main rows, solutions are found for the configuration of wind turbines that then emerges according to the wind direction.
The model complex will be adjusted and calibrated with measurements in the near future.
Partners: Energi- og Miljødata (EMD), Denmark.

Sponsor/client: Danish Energy Authority, energy research programme (EFP).
Contact: Sten Frandsen, sten.frandsen@risoe,dk, tel. +45 4677 5072.

Improved design base for large wind turbine blades – phase 2
Programme: VIM, project no. 1120 141-00, start September 2003, cont.
● The focal point of this project is the compressive strength of fibre composite blade structures with imperfections. The project aims to improve the design basis by
• identifying imperfections at different levels from materials to a global level,
• developing analytical and numerical models for the quantification of the effect on blade strength of such imperfections,
• performing experimental tests with elementary loads on basic components in order to verify analytical and numerical models.
Partners: Risø National Laboratory, Materials Research Department,
Aalborg University, Denmark,
Technical University of Denmark, Denmark,
Vestas Wind Systems A/S, Denmark,
LM Glasfiber A/S, Denmark.
Sponsor/client: Danish Energy Authorithy, energy research programme (EFP).
Contact: Kim Branner, kim.branner@risoe.dk, tel. +45 4677 5470.

Services to the Danish Energy Authority
Programme: VIM, project no. 1120 299-2, start date 10.1. 2001.
● The primary task is to assist the Danish Energy Authority in managing the 'Danish Approval Scheme for Wind Turbines'. Other activities in 2003 were the maintenance and development of rules and regulations for technical approval of wind turbines. The agreement includes a number of defined activities with individual scopes.
We have also rendered assistance to the Danish Energy Authority in formulating the strategy and action plan for research and development from 2000 to 2004. This included the evaluation of individual applications for R&D funding under the energy research programmes EFP and UVE.
Partners: Danish Energy Authority.
Furthermore, a number of companies and institutions in Denmark and abroad are involved in these activities as members of an advisory committee, a technical committee and various ad hoc groups.
Sponsor/client: Danish Energy Authority, Denmark.
Contact: Jørgen Lemming, joergen.lemming@risoe.dk, tel. +45 4677 5086.

General programme for information activities, international cooperation, and R&D related to standardization and new test methods
Programme: VIM, project no. 1120 301, start date 10.1. 2001, cont.
● This programme encompasses activities that are supplementary to the activities sponsored by the Danish Energy Authority and others. A total of eight different tasks are defined under this internal programme, in which most sections of the Wind Energy Department participate.
Partners: None.
Sponsor/client: None.
Contact: Jørgen Lemming, joergen.lemming@risoe.dk, tel. +45 4677 5086.

Wind Energy Systems, VES

Research programme
Head of Programme: Jens Carsten Hansen

It is the purpose of this programme to contribute new knowledge, computational models and experimental verification for the analysis and development of wind turbines with regard to electric and control characteristics as well as grid and systems integration of wind energy. In a co-operation with Aalborg University we pursue these goals through a long-term strategic and applied research and development effort which is directed at control principles for the operation and application of wind turbines, their electromechanical components as well as the integration of wind energy into power systems.
Our goals are
- to develop new control concepts for the optimization of wind turbine loads, production and power quality,
- to assess and to test the potential applications of alternative electromechanical components for wind turbines and wind power systems, including new advanced generators and power electronics, and
- to develop methods and concepts for the electrical integration of renewable energy – wind energy in particular – into centralized as well as isolated power systems.

VES projects

Condition monitoring of wind turbine
Programme: VES, project no. 1115 019-00, start date 4.4. 2000, cont.
- The objective of this project is to further develop the condition monitoring system of modern wind turbines in order to reduce down time and maintenance costs. In order to avoid operation in damaging conditions and reduce or stop production before serious breakdown of main components, we seek to improve present-day methods for monitoring the loads and the operating conditions of rotor as well as generator/bearings/gearbox and overall state of health. Project activities have been quiescent during 2003 due to the altered circumstances of our industrial partner.

Partners: Vestas Wind Systems A/S, Denmark,
Aalborg University, Institute of Energy Technology, Denmark.
Sponsor/client: Danish Energy Authority, energy research programme EFP 2000.
Contact: Henrik Bindner, henrik.bindner@risoe.dk, tel. +45 4677 5050.

Wind plus
Programme: VES, project no. 1115 020-00, start date 4.4. 2000, end 1.10.2003.
- The focus of this project was the development of operating and control strategies for storage systems in wind/diesel power systems. The project has been closed due to a lack of available demonstration sites.

Partners: Vergnet SA, France,
Energy research Centre of the Netherlands (ECN), Netherlands,
ABB Ltd (Asea Brown Boveri), Switzerland,
CINAR SA, Greece,

SgurrEnergy, United Kingdom.
Sponsor/client: EU.
Contact: Henrik Bindner, henrik.bindner@risoe.dk, tel. +45 4677 5050.

Gaia wind turbine for use in wind/diesel systems and as stand-alone
Programme: VES, project no. 1115 022-1, start date 18.1. 2001, cont.
● An 11 kW Gaia wind turbine has been modified so as to operate in a wind/diesel system, and the operation subsequently documented by measurements. Another major part of the project involves further development of the wind turbine, thus enabling it to operate without other power generating units such as a diesel generator. The stand-alone version of the wind turbine has also been tested and its performance is now being documented.
Partners: Gaia Wind A/S, Denmark,
Mita-Teknik A/S, Denmark,
Aalborg University, Denmark.
Sponsor/client: Danish Energy Authority, UVE (development programme for renewable energy).
Contact: Henrik Bindner, henrik.bindner@risoe.dk, tel. +45 4677 5050.

Simulation and verification of transient events in large wind power installations
Programme: VES, project no. 1115 024-1, start date 1.7. 2000, completed 31.12. 2003.
● The objective of this project was to assess the ability of various dedicated power system simulation tools to predict the response of wind farms to transient events such as grid faults in the power system. The Danish transmission system operators has made the simulation of this response a prerequisite for the connection of large wind farms directly to the transmission system. In a case study we have applied models for the 6×2 MW wind farm in Hagesholm. These models were developed by means of power system simulation tools DIgSILENT and EMTDC.
Partners: NVE (North-West Zealand Energy Supply Company), Denmark,
Aalborg University, Denmark,
DanControl Engineering A/S, Denmark.
Sponsor/client: Elkraft System a.m.b.a., Denmark.
Contact: Poul Sørensen, poul.soerensen@risoe.dk, tel. +45 4677 5075.

Investire
Programme: VES, project no. 1115 027-01, start date 8.6. 2000, completed 31.12. 2003.
● The main objectives of the Investire network (Investigations on Storage Technologies for Intermittent Renewable Energies) were the review and assessment of current storage technologies in the context of renewable energy applications, in order to facilitate an exchange of information among the main actors and to propose appropriate research and technological development (RTD) for the future. In detail, this includes
• the review of possible storage technologies that are suited to renewable energy systems,
• the identification of research priorities and publication of a long-term RTD roadmap,
• encouraging the formation of new RTD partnerships, and

• fostering cooperation between battery manufacturers and designers/suppliers of renewable energies systems.
Partners: Renewable Energies Group of the Establishment of Cadarache (GENEC), The French Atomic Energy Commission (CEA), France, (co-ordinator), and 34 partners from Europe and outside.
Sponsor/client: European Commission, D-G for Research, Fifth Framework Programme.
Contact: Per Lundsager, per.lundsager@risoe.dk, tel. +45 4677 5045.

PSO green power converter
Programme: VES, project no. 1115 028-1, start date August 2001, cont.
● The purpose of this project is to develop new and cost-effective power converters for the connection of photovoltaic (pv) panels to the grid. We shall particularly emphasize low cost, high reliability and the suitability for mass production. The tasks include
• specification, modelling and simulation of new converter topologies,
• selection of best topology, and
• laboratory as well as field testing.
Partners: Aalborg University, Denmark,
Danish Technological Institute (TI), Denmark,
Danfoss A/S, Denmark.
Sponsor/client: Elkraft System a.m.b.a., Denmark.
Contact: Henrik Bindner, henrik.bindner@risoe.dk, tel. +45 4677 5050.

Benchmarking
Programme: VES, project no. 1115 029-01, start date 2.1. 2002, cont.
● This project concerns the development of test procedures for benchmarking energy storage systems and related components. Results will enable users to select the optimum energy storage product for their specific application. Our task includes:
• establishing a renewable energy systems database based on actual system tests,
• classifying and categorizing various renewable energy systems,
• testing and describing the performance of various battery systems,
• benchmarking batteries and establishing a guide for the use of batteries in renewable energy systems, and
• communicating our results to stakeholders.
Manufacturers may also use our results for defining the category of RES (renewable energy system) to which their product is best suited and to estimate the expected lifetime for a well-defined category of use. We are working in close contact with the International Electrotechnical Commission (IEC) and their relevant committees, and this project will provide a framework for defining detailed technical standards, appropriate for a maturing industry.
Partners: the Fraunhofer Institute for Solar Energy Systems (ISE) (co-ordinator), Germany,
National Renewable Energy Laboratory (NREL), US Dept. of Energy, USA, and
10 European contractors, including Risø National Laboratory.
Sponsor/client: European Commission, Directorate-General for Research, Fifth Framework Programme.
Contact: Per Lundsager, per.lundsager@risoe.dk, tel. +45 4677 5045.

Operation and control of large wind turbines and wind farms
Programme: VES, project no. 1115 030-1, start date 1.6. 2002, cont.
● The purpose of this project is to examine the possibilities of control of a variety of wind turbines and wind farm concepts. To this end we have developed models and wind farm strategies aimed at
• improving the integration of wind power into the grid, i.e. supporting the control of grid frequency (by power control of the wind farm) and grid voltage (by reactive power control of the wind farm), and improving the influence on grid power quality,
• maximizing power production, and
• maximizing the lifetime of wind turbines by reducing mechanical loads.
The wind farm control will be based on an interpretation of signals from the individual wind turbine controllers. The signals will be used for short-term predictions – from seconds to minutes – of the wind speed, thus enabling each wind turbine controller to respond accordingly.
We shall also investigate the potentials of optimizing wind turbine lifetime and the energy production ratio by means of a revised operational strategy for the individual wind turbine. It is one of our main objectives to clarify this by decreasing the power production to an optimum that reflects present loads as well as the price of electricity.
Partners: Technical University of Denmark,
Aalborg University, Denmark,
Energi E2 A/S, Denmark.
Sponsor/client: Elkraft System a.m.b.a., Denmark.
Contact: Poul Sørensen, poul.soerensen@risoe.dk, tel. +45 4677 5075.

Dynamic phase compensation
Programme: VES, project no. 1115 031-1, start date 12.10. 2001, cont.
● The objective of this project is to develop and test a dynamic phase compensation unit for wind turbines with directly connected induction generators. This particular compensation unit is based on thyristor-switched capacitors, contrary to the mechanical contactors used by conventional compensations.
Mita-Teknik A/S is in charge of developing the compensation unit, whereas Risø is responsible for testing the unit and for developing simulation models in cooperation with Aalborg University. The influence of the new unit on power quality and component lifetime is analysed. For the development of simulation models for the compensation unit as well as wind turbine and grid, we use Matlab® and Simulink®. These programs are also employed for the implementation of a flickermeter model.
Partners: Mita-Teknik A/S, Denmark,
Aalborg University, Denmark.
Sponsor/client: Danish Energy Authority, Denmark.
Contact: Poul Sørensen, poul.soerensen@risoe.dk, tel. +45 4677 5075.

Wind power integration in a liberalized electricity market – WILMAR
Programme: VES, project no. 1115 033-01, start 2003, end 2005.
● A fast introduction of large amounts of intermittent renewable power such as wind power may cause technical and economic problems to the power systems. These problems may be due to the unpredictability of wind power or to an imbalance between local power demand and intermitting power production, subsequently causing instabilities to the grid. The main objective of this project is to investigate these problems and develop a modelling tool for simulating alternative solutions, thus

providing a firm basis for decision-making by system operators, power producers and energy authorities.
The possibilities for integrating a fluctuating power production by optimizing the interaction of existing units in a given electricity system and the possibilities lying in power exchange between regions are both evaluated, as is the performance of dedicated integration technologies such as electricity storage.
Partners: Systems Analysis Department (project coordinator), Risø National Laboratory, Denmark,
Elsam A/S, Denmark,
SINTEF Energy Research, Norway,
The Royal Institute of Technology (KTH), Sweden,
Technical University of Denmark,
Elkraft System a.m.b.a., Denmark,
Universität Stuttgart, Germany,
Nord Pool Consulting, Norway,
VTT Technical Research Centre of Finland.
Sponsor/client: European Commission, Directorate-General for Research.
Contact: Per Nørgård, per.norgaard@risoe.dk, tel. +45 4677 5068.

Danvest/NEG Micon wind/diesel testing and documentation
Programme: VES, project no. 1115 035-01, start date 1.1. 2003, cont.
● This project concerns the development as well as testing and documentation of a wind/diesel system concept. Risø is involved in the documentation part of the project, and we are responsible for measurements and data analysis. We have investigated and documented the performance of the system in order to verify the operating strategy and systems control.
Partners: Danvest Energy A/S (subsidiary of NEG-Micon), Denmark.
Sponsor/client: Danish Energy Authority, UVE.
Contact: Henrik Bindner, henrik.bindner@risoe.dk, tel. +45 4677 5050.

IEA – Dynamic models of wind farms for power system studies
Programme: VES, project no. 1115 036-01, start date 1.7. 2002, cont.
● This project supports Danish participation in the International Energy Agency (IEA) Wind Agreement, Annex XXI; 'Dynamic models of wind farms for power system studies'. The overall objective of Annex XXI is to assist the planning and design of wind farms by facilitating a coordinated effort to develop wind farm models that are suitable for evaluating the dynamic and the transient stability of power systems. Immediate objectives are:
• The establishment of an international forum for exchanging knowledge and experience regarding wind farm modelling for power system studies.
• Development, description and validation of wind farm models. In this case, wind farm models are to be developed by the individual participants of the Annex, whereas the description and validation will be coordinated by the Annex in order to assess the state of the art and pinpoint the key issues for further development.
• The compilation and operation of a common database on benchmark testing of wind turbine and wind farm models in order to ensure high quality models.
Partners: SINTEF Energy Research, Norway,
Chalmers University of Technology, Sweden,
University of Manchester Institute of Science and Technology (UMIST), United Kingdom,

National Institute of Engineering and Industrial Technology (INETI), now; INETInnovation, Portugal,
Energy research Centre of the Netherlands (ECN), Netherlands,
VTT Technical Research Centre of Finland, Finland,
National Renewable Energy Laboratory (NREL), USA,
University College Dublin, Ireland.
Sponsor/client: Danish Energy Authority.
Contact: Poul Sørensen, poul.soerensen@risoe.dk, tel. +45 4677 5075.

IPSYS
Programme: VES, project no. 1115 037-00, start date 1.1. 2003, cont.
● These are activities aimed at the development of a simulation tool for the analysis and design of distributed power systems with a large amount of renewable energy from various sources and a large number of interacting supervisory controllers. The project is particularly focussed on the modelling of the system's supervisory control level, i.e. unit commitment and dispatch, and the resulting performance in terms of fuel consumption and utilization of renewable energy potential. This software tool also includes flexible modelling, allowing the modelling of an electrical system as well as a heat or water supply system, and the interaction between the two through components and controllers.
Partners: None.
Sponsor/client: None.
Contact: Henrik Bindner, henrik.bindner@risoe.dk, tel. +45 4677 5050.

Hydrogen energy foresight in the Nordic countries
Programme: VES, project no. 1115 038-1, start 2003, end 2004.
● Hydrogen used as an energy carrier is generally accepted as a promising future replacement for fossil fuels, suitable for addressing the issues of environmental degradation and energy supply. The realisation of the hydrogen vision requires concerted action among governments, science, and industry in the Nordic countries. A number of hydrogen-related R&D activities have already been initiated, but the question remains, how to implement the necessary strategic intelligence, synergy, and critical mass in Nordic R&D in order to realise the hydrogen society. The hypothesis is that technology foresight (TF) reaches across disciplinary as well as institutional and national boundaries. It aims to build synergy and critical masses within selected areas of strategic importance to hydrogen energy, and also at positioning common Nordic actions and alliances in a broader international context.
The objectives of the Nordic initiative are
• to develop socio-technical scenarios for a future hydrogen society and explore the roads to commercialization in production, transport, storage and utilisation,
• to contribute decision support for companies, research institutes and public authorities in order for them to prioritize R&D and develop effective framework policies, and
• to maintain and develop scientific and industrial networks.
VEA plays a modest role in this project as subcontractor to the Systems Analysis Department.
Partners: Risø National Laboratory, Systems Analysis Department (project coordinator),
VTT Technical Research Centre of Finland, Finland,
The Swedish Defence Research Agency (FOI), Sweden,

Norwegian University of Science and Technology (NTNU) and SINTEF, Norway,
Icelandic New Energy Ltd. and the University of Iceland, Iceland,
Norsk Hydro ASA, Norway,
Swedish Hydrogen Forum (H2 Forum), Sweden,
Fortum Oy, Finland,
Wärtsilä Corporation, Finland,
The Society of Danish Engineers (IDA), Denmark,
Energi E2 A/S, Denmark,
AGA Gas AB, Sweden,
IRD Fuel Cells A/S, Denmark,
Vattenfall AB, Sweden,
ABB Finland, Finland,
Danish Gas Technology Centre, Denmark.
Sponsor/client: Nordic Industrial Fund, as of January 2004; the Nordic Innovation Centre.
Contact: Per Nørgård, per.norgaard@risoe.dk, tel. +45 4677 5068.

Nordic project on climate and energy – CE
Programme: VES, project no. 1115 039-00, start date 1.10. 2003, cont.
● This project concerns a comprehensive assessment of the effect of climate change on renewable energy resources in the Nordic countries; that is to say electricity produced from hydro, wind, bio fuels, and solar energy. We are responsible for assessing the wind energy resource and production potential, for modelling the integration of wind power production into the Nordic grid and for analysing the sensitivity of this potential to climate change.
Climate scenarios in this project originate from two general circulation models, HADAM3H from Hadley Centre, UK, and ECHAM4 from the Max Planck Institute of Meteorology in Germany. For the development and validation of downscaling methods we shall employ a dynamical as well as a statistical approach.
Maps of future wind climates will be produced from two emission scenarios, A2 and B2, and we shall use data from the reference period 1990-2000 to validate the different approaches.
Dynamical downscaling will be compared with statistical downscaling, i.e. a relationship between current wind-related variables (measurement-based) and GCM (general circulation model) output, and this relationship will be used to determine changes in the future wind climate.
The impact of climate change on wind turbine performance will be considered, particularly with regard to wind speeds, icing and low level jets which are important in the Nordic region, and we shall analyse the consequences with regard to wind turbine extreme loads and design standards. Ultimately, the integration of wind power into Nordic energy supply, distribution, and transmission systems will be considered.
Partners: Finnish Meteorological Institute (FMI), Finland,
VTT Technical Research Centre of Finland, Finland,
Uppsala University, Sweden,
The Icelandic Meteorological Office, Iceland (associated partner).
Sponsor/client: Nordic Energy Research Programme and the energy sector in the Nordic countries.
Contact: Niels-Erik Clausen, niels-erik.clausen@risoe.dk, tel. +45 4677 5079.

Grid-connected wind farm extension project, Cape Verde

Programme: VES/INR, project no. 1170 003-00, start date 15.3. 2001, cont.
● We render consultancy and technical assistance to the privatised power company Electra, S.A.R.L. and the Government of Cape Verde for development and monitorship. The project concerns Electra's obligation towards the Government of Cape Verde and the World Bank to expand the capacity of Cape Verde's wind powered electricity generation by installing an additional capacity of up to 4.8 MW, 1.8 MW and 1.2 MW respectively, on the main grids of the islands of Santiago, Sao Vicente and Sal. Our services include
• meteorological measurements,
• power systems analyses,
• consultancy regarding an EPC contract (engineering, procurement and construction),
• project performance evaluation, and
• first year operation and maintenance assistance.
Partners: Elsam Engineering A/S, Denmark,
Carl Bro Group, Denmark.
Sponsor/client: Programa Energia, Água e Saneamento, Praia, Cape Verde with support from the World Bank, Global Environment Facility (GEF).
Contact: Jens Carsten Hansen, carsten.hansen@risoe.dk, tel. +45 4677 5074

Wind resource assessment in the Dominican Republic
Programme: VES/INR, project no. 1170 006-00, start date 15.9. 2001, cont.
● Our consultancy services concern the siting of four masts for wind measurements in potential wind farm areas in the Dominican Republic. Services include the selection of equipment and instrumentation, data processing, and a subsequent presentation of results on a dedicated homepage. We will also provide wind climate documentation after one and two years of operation and we shall supervise measurements continually. So far, we have assisted at the evaluation of a number of commercial proposals for a 7 MW wind farm.
Partners: MetSupport ApS, Denmark.
Sponsor/client: Consorcio Enèrgetico Punta Cana-Macao, S.A. (CEPM), Dominican Republic.
Contact: Niels-Erik Clausen, niels-erik.clausen@risoe.dk, tel. +45 4677 5079.

Wind energy study for HELCO; the Big Island of Hawaii
Programme: VES/INR, project no. 1170 007-00, start date 1.10. 2001, completed December 2003.
● We have conducted a wind resource study for Hawaii Electric Light Company, Inc. (HELCO) at Lalamilo, Big Island of Hawaii.
Partners: *None.*
Sponsor/client: Hawaii Electric Light Company, Inc. (HELCO), Hawaii.
Contact: Jens Carsten Hansen, carsten.hansen@risoe.dk, tel. +45 4677 5074.

Wind Farm project in Latvia
Programme: VES/INR, project no. 1170 016-00, start date 1.5. 2003, finalized in 2003.
● For a Danish wind farm developer we have produced a proposal layout for a 100 MW wind farm in Latvia, near the Baltic coastline. The annual energy production of the wind farm has been estimated by means of wind measurements from April 2001 to May 2002, and 10 years of long-term measurements from Latvian meteorological

stations. We also assessed the financial viability of the project by calculation of financial key indicators such as IRR (internal rate of return), ROE (return on equity) and NPV (net present value) at various electricity tariffs.
Partners: None.
Sponsor/client: Dka Consult ApS, Denmark.
Contact: Niels-Erik Clausen, niels-erik.clausen@risoe.dk, tel. +45 4677 5079.

Development of offshore wind energy course
Programme: VES/INR, project no. 1170 017-00, start date 1.7. 2003, finalized September 2003.
● This activity concerns the development and implementation of the first offshore wind energy course.
The course covers the major development and implementation aspects of an offshore wind project – from site selection to wind farm operation. The topics are:
• wind resource assessment
• offshore measurements
• short-term forecast of wind farm production
• structural loads
• wind turbine foundations
• grid connection
• wind power plant operation
• offshore project certification.
Partners: None.
Sponsor/client: Industrial Technology Research Institute (ITRI), Taiwan.
Contact: Niels-Erik Clausen, niels-erik.clausen@risoe.dk, tel. +45 4677 5079.

SEI offshore wind energy and industrial development
Programme: VES/INR, project no. 1170 018-00, start date 1.9. 2003, cont.
● This project will support the Government of Ireland and Sustainable Energy Ireland (SEI) when analysing and developing targets, programmes and policies related to the implementation of wind energy in the Republic of Ireland.
The study consists of two tasks:
• The identification of key requirements for meeting potential future targets for the deployment of offshore wind energy in Ireland.
• The identification of potential opportunities for the development of an industry supplying the wind energy market in Ireland and overseas.
It is the aim of this study is produce an estimate of the contribution from offshore wind energy to the fulfilment of Ireland's international obligations concerning the mitigation of global climate change.
Furthermore, the project is to produce an estimate of the potential volume of services and goods from offshore as well as onshore wind energy activities in Ireland. We will outline the present industrial capacity for supplying the wind energy industry and suggest relevant opportunities for expanding this capacity. Finally, we will suggest policies and measures for stimulating the development of industrial capacity.
Partner: BTM Consult ApS, Denmark,
The Danish Energy Authority, Denmark.
Partners: None.
Sponsor/client: Sustainable Energy Ireland (SEI), Ireland.
Contact: Niels-Erik Clausen, niels-erik.clausen@risoe.dk, tel. +45 4677 5079.

Site calibration, 60 MW wind farm at Zafarana, Egypt
Programme: VES/INR, project no. 1170 076-02, start date 1996, cont.
● This project provides a calibration of terrain descriptions for wind flow modelling, using an adaptation of the IEC's (International Electrotechnical Commission) site calibration methodology. The site in question is a 60 MW wind farm at Zafarana, Egypt. Along with experience gained from the calibration process, this project will also provide useful information about the local conditions for accurate micro-siting of wind turbines. Furthermore, we will collect ample information on wind conditions – including turbulence characteristics – before and after the installation of a wind farm. Only activity in 2003 is data collection. Further data analyses await the completion of the wind farm.
Partners: None.
Sponsor/client: Danish International Development Assistance (Danida), Denmark.
Contact: Jens Carsten Hansen, carsten.hansen@risoe.dk, tel. +45 4677 5074.

Capacity building on the technological and economic integration of wind energy and other relevant renewable energy technologies into the electricity systems of Pacific island countries
Programme: VES/INR, project no. 1170 089-00, start date 25.1. 2000, cont.
● Potential sites for wind turbines will be visited in connection with an expansion of the South Pacific Wind Monitoring Programme. Based on findings from previous activities and the installation of a prototype wind turbine for experimental studies and capacity building for selected wind power cases, a curriculum and proposals for course material will be developed in close collaboration with regional institutions and teachers. The resulting material will be used at the University of South Pacific.
Partners: UNEP Collaborating Centre on Energy and Environment (UCCEE), coordinator at Risø National Laboratory, Denmark,
UNEP, Division of Technology, Industry, and Economics (DTIE), Energy and OzonAction Branch.
Sponsor/client: United Nations Environment Programme (UNEP).
Contact: Per Nørgård, per.norgaard@risoe.dk, tel. +45 4677 5068.

Wind atlas for Egypt
Programme: VES/INR, project no. 1170 104-00, start date 19.12. 1997, cont.
● The purpose of this project is to improve conditions for the development of wind power on a large scale in Egypt. We will provide the following:
• A wind atlas for Egypt with particular emphasis on regions/locations with attractive wind regimes.
• A comprehensive and updated wind atlas for the Gulf of Suez.
• A decision tool regarding environmental impacts, bird migration in particular.
• Recommendations for a common framework of wind farm planning in the Gulf of Suez.
• A transfer of knowledge and experience to Egyptian partners regarding the methodology applied to establishing a wind atlas.
Partners: Hedeselskabet Miljø og Energi A/S, Denmark,
National Environmental Research Institute (NERI), Denmark.
Sponsor/client: Danish International Development Assistance (Danida), Denmark.
Contact: Jens Carsten Hansen, carsten.hansen@risoe.dk, tel. +45 4677 5074.

NREA/Danida 60 MW wind farm project at Zafarana, Egypt
Programme: VES/INR, project no. 1170 106-00, start date January 1998, completed December 2003
● As subcontractor to COWI A/S we have acted as consultants to Egypt's New and Renewable Energy Authority (NREA) and Danida, providing the following;
• Pre-award phase: Proposals for the layout and siting of wind turbines, a calculation of energy outputs, recommendations for the optimum use of land, and a review of power performance estimates as submitted by the tenders.
• Design phase: Preparation of a detailed layout of the wind farm including optimisation of annual energy production.
• Construction phase: A verification of power curve measurements supplied by an independent third party.
Partners: COWI A/S, Denmark (leading consultant).
Sponsor/client: Danish International Development Assistance (Danida), Denmark.
Contact: Jens Carsten Hansen, carsten.hansen@risoe.dk, tel. +45 4677 5074.

National wind turbine test station, India
Programme: VES/INR, project no. 1170 111-00, start date 1.1. 1999, end 2004.
● The main objective of this project is to promote and accelerate the utilisation of wind power in India by establishing national facilities for
• testing and certification of wind turbines,
• the preparation of standards and certification rules, and
• for monitoring the technical performance of wind turbines.
During the initial phase of the project, a core professional organization as well as the facilities for stationary and field power performance measurements were established and a preliminary type approval system was developed.
In the following phase, a full professional organization was established as were the facilities for complete stationary and field testing of wind turbines. The provisional type approval system is now implemented and a final type approval system has been completed, based on international standards and ready for implementation.
Major components of the project are human resource and institutional development, workshops, and on-the-job training for local staff during testing and certification, as well as technical support regarding the equipment and facilities.
Partners: Det Norske Veritas (DNV), Norway and India,
PEM Consult a/s, Denmark,
NIRAS – Rådgivende Ingeniører og Planlæggere A/S, Denmark.
Sponsor/client: Danish International Development Assistance (Danida), Denmark.
Contact: Per Lundsager, per.lundsager@risoe.dk, tel. +45 4677 5045.

Wind measurements and wind power feasibility at selected sites in Tanzania
Programme: VES/INR, project no. 1170 118-00, start date 1.1. 2000, completed December 2003.
● The objectives of the assignment were
• to provide the tools and build the capacity in Tanzania to enable wind resource assessment, adequate for determining the feasibility of wind power utilization at selected locations,
• to determine the feasibility of establishing a pilot wind farm connected to the public power supply system in one of four pre-selected localities.
Four sets of measurement equipment were supplied and installed. For one year measurements were carried out at the pre-selected sites, and subsequently a number of

data analyses, a feasibility study and recommendations were made for selected sites. The project was completed with a two-day workshop on wind resource assessment and wind power project feasibility study techniques.
Partners: Tanzania Electric Supply Company Ltd. (TANESCO), Tanzania, Tanzania Ministry of Energy.
Sponsor/client: Danish International Development Assistance (Danida), Denmark.
Contact: Per Nørgård, per.norgaard@risoe.dk, tel. +45 4677 5068.

Test and Measurements, TEM

Technical programme
Head of Programme: Jørgen Højstrup

The purpose of this programme is to develop new methods for meteorological measurements and to further develop current methods for the experimental determination of wind turbine characteristics. On behalf of Danish authorities we perform the development underpinning accredited test methods in this particular field. We also develop test methods for industrial applications, and the outcome of our work is communicated to the wind power industry on a regular basis.
Results are to be obtained through a long-term and strategic research effort. Mid-term goals concern the development of experimental methods for defining

- wind turbine performance,
- loads, dynamics and stability,
- aerodynamic flow conditions of full-scale wind turbine rotors, and
- the meteorological and chemical processes as well as the characteristics of the atmosphere.

Furthermore, we engage in the development and implementation of hardware and software for measuring processes and data management systems.
In 2003 the programme was very successful in attracting large commercial measurement projects, resulting in a very busy year and a very satisfactory financial result.

TEM projects

In 2003, this programme had 11 large and seven smaller confidential projects.

Management of wind turbines and workshop (at the Test Station)
Programme: TEM, project no. 1125 002-00, start date 17.1. 2000, cont.

- The purpose of this project is to maintain and operate the wind turbines erected at Risø and the associated workshop. Proceeds from the sale of electricity generated by the turbines cover expenses in this project.

Partners: None.
Sponsor/client: NESA, Denmark.
Contact: Per Harvøe, per.harvoe@risoe.dk, tel. +45 4677 5038.

UVE måling Middelgrunden
Programme: TEM, project no. 1125 116-00, start date 1.1. 2003, concluded 31.12. 2003

- The purpose of this project is measurement of power production in wake conditions and measurements of wake structure.

Partners: Elkraft,
Bonus Energy A/S,
NEG Micon A/S.

Sponsor/clients: Danish Energy Authority, development programme for renewable energy (UVE).
Contact: Søren Markkilde Petersen, soeren.m.petersen@risoe.dk, tel. +45 4677 5043.

Standardisering IEC-TC88 MT12
Programme: TEM, project no. 1125 123-01.
● Maintenance and updating of standards relating to the power performance of wind turbines.
Partners: International Electrotechnical Commission, IEC.
Sponsor/client: Three Danish wind turbine manufacturers.
Contact: Troels Friis Pedersen, troels.friis.pedersen@risoe.dk, dk, tel. +45 4677 5042.

Wind energy SODAR evaluation (WISE)
Programme: TEM, project no. 1125 117-01, start date 2002.
● The purpose of WISE is to investigate the feasibility of using the remote sensing technique SODAR (= sound detection and ranging) in the field of wind energy. The project includes
- establishment of operational characteristics,
- calibration of the SODAR,
- intercomparison of different brands of SODARS,
- filtering techniques,
- power performance measurements using SODAR, and
- operation of SODAR in complex terrain and remote sites.

Partners: Energy research Centre of the Netherlands (co-ordinator),
Centre for Renewable Energy Sources (CRES), Greece,
University of Salford, United Kingdom,
Windtest, Germany,
German Wind Energy Institute (DEWI), Germany,
Forschungszentrum Karlsruhe, Institute for Meteorology and Climate Research, IMK-IFU, Germany.
Sponsor/client: EU, Sixth Framework Programme.
Contact: Ioannis Antoniou, ioannis.antoniou@risoe.dk, tel +45 4677 5082.

Accurate wind speed measurements in wind energy
Programme: TEM, project no. 1125 124-01, start date 1.4. 2003.
● The purpose of this project is to improve tools and methods for assessing the accuracy of cup anemometers for wind energy measurements.
Partners: German Wind Energy Institute (DEWI), Germany
Swedish Defence Research Agency, Sweden
Centre for Renewable Energy Sources (CRES), Greece
Energy research Centre of the Netherlands (ECN), Netherlands,
Universidad Politécnica de Madrid, Spain.
Sponsor/client: EU
Contact: Troels Friis Pedersen, troels.friis.pedersen@risoe.dk, tel. +45 4677 5042.

Power performance workshop, HiH
Programme: TEM, project no. 1125 126-01, start date 18.3. 2003.
● Workshop on power performance verification and associated warranties for engineers employed by various Danish manufacturers.
Partners: None.

Sponsor/client: Herning Institute of Business Administration and Technology (HIH).
Contact: Jørgen Højstrup, jorgen.hojstrup@risoe.dk, tel. +45 4677 5092.

Development and documentation of new and existing methods for remote and in-situ measurements of wind speed
Programme: TEM, project no. 1125 129-01, start date 1.5. 2003, cont.
- The purpose of this project is to verify, calibrate and improve remote acoustic and optical sensors for wind speed measurements. Current models for wind speed and turbulence profiles are not sufficiently accurate at today's wind turbine heights and therefore need to be improved. In order to obtain the measurements for this project, comprehensively equipped meteorology masts are required in simple terrain, and such facilities are available to us at the department's Test Station for Large Wind Turbines at Høvsøre.

Partners: None.
Sponsor/client: Danish Energy Authority, energy research programme (EFP).
Contact: Jørgen Højstrup, jorgen.hojstrup@risoe.dk, tel. +45 4677 5092.

Minor contracts
Programme: TEM, project no. 1125 500-01, start date 1.1. 2000, cont.
- These contracts concern minor commissions and the supply and development of measuring equipment. Clients are mainly companies or institutions working with wind energy, meteorology or environmental protection.

Partners: None.
Sponsor/client: Various.
Contact: Ole Frost Hansen, ole.frost@risoe.dk, tel. +45 4677 5525.

Development, manufacture and sale of cup anemometers
Programme: TEM, project no. 1125 502-01, 1.1. 2003, cont.
- The Risø cup anemometer has been sold in large numbers to manufacturers and developers in Denmark and worldwide.

Partners: None.
Sponsor/client: Various.
Contact: Ole Frost Hansen, ole.frost@risoe.dk, tel. +45 4677 5525.

Ørestad wind station
Programme: TEM, project no. 1125 528-01, start date 1.1. 2003.
- An offshore mast has been mounted with data logging equipment with satellite communication and near to real time display of data on a web page.

Partners: None.
Sponsor/client: Confidential.
Contact: Ole Frost Hansen, ole.frost@risoe.dk, tel. +45 4677 5525.

Small measuring stations
Programme: TEM, project no. 1125 600-01, start date 20.11. 1997, cont.
- The TEM programme is in charge of the establishment, service and data management of a number of small meteorological measuring stations on behalf of specific projects or as part of the department’s long-term strategic measurements.

Partners: None.
Sponsor/client: Internal, and various external sponsors.
Contact: Jørgen Højstrup, jorgen.hojstrup@risoe.dk, tel. +45 4677 5092.

The Risø Mast
Programme: TEM, project no. 1125 600-01, start date 6.6. 1957, cont.
- This programme concerns the monitoring of meteorological conditions at Risø National Laboratory (still a nuclear facility), and the establishment of a set of climatological reference data for Denmark. We produce profiles of wind speed, wind direction and air temperature as well as measurements of wind direction variance, relative humidity, barometric pressure, precipitation, duration of sunshine, and insolation. Occasionally, we test various meteorological sensors.

Partners: None.
Sponsor/client: None.
Contact: Jørgen Højstrup, jorgen.hojstrup@risoe.dk, tel. +45 4677 5092.

Power performance measurements
Programme: TEM, project no. 1155 400-01, start date February 2001, cont.
- Power performance measurements on two wind turbines in Italy.

Partners: None.
Sponsor/client: Wind turbine manufacturer, Denmark.
Contact: Troels Friis Pedersen, troels.friis.pedersen@risoe.dk, tel. +45 4647 5042.

Instrumentation of NTK 500 wind turbine for student use
Programme: TEM, project no. 1191 500-02, start date 1.1. 2003.
- A 500 kW wind turbine has been mounted with instruments for basic measurements, and data have been made available remotely. The wind turbine is used for various students' projects.

Partners: Wind Energy Educational Programme at VEA, Risø National Laboratory, Technical University of Denmark.
Sponsor/client:
Contact: Uwe Schmidt Paulsen, uwe.schmidt.paulsen@risoe.dk, tel +45 4677 5044.

Sparkær Blade Test Centre, SPK

Technical programme
Head; Carsten Skamris

The purpose of this programme is
- to determine dynamic characteristics, and to conduct static and fatigue testing of wind turbine blades as well as other experimental investigations as a commercial enterprise for the wind turbine industry,
- to develop new, more efficient and informative methods for blade testing,
- to participate in various Risø research projects that involve an experimental investigation of blades.

SPK projects

Blade testing
Programme: SPK, project no. 1165 xxx, varying start dates.
- The Sparkær Centre is an accredited test laboratory for wind turbine blades.

Activities include testing of the static and fatigue strength of blades from a number of manufacturers, domestic as well as international.
Dynamic behaviour such as natural frequencies and damping are also measured, and we perform modal analyses and stiffness tests. Test procedures are carried out either at the Wind Energy Department's facilities in Sparkær, Jylland, or as field measurements. The identities of our clients as well as test procedures and results are strictly confidential.
Partners: None.
Sponsor: None.
Contact: Carsten Skamris, c.skamris@risoe.dk, tel. +45 4677 5066.

Development and verification of methods for determining modal shapes of wind turbine blades
Programme: SPK, project no. 1165 501-01, start date 1.11. 2001, end February 2003.
- The scope of this project is to make modal analysis practicable by developing the method as well as the equipment. Furthermore, the project is to demonstrate the feasibility of obtaining useful and reproducible results. There is particular focus on the equipment, software and the method of measuring, including survey of the blade, the principle of excitation, and mounting of the blade on the test rig.

Partners: None.
Sponsor: Danish Energy Authority, renewable energy programme (UVE),
Contact: Henrik Broen Pedersen, henrik.broen.pedersen@risoe.dk, tel. +45 8664 5600

Test Station for Large Wind Turbines, Høvsøre, HØV

Technical programme

This programme is a sub-division of the Sparkær Blade Test Centre. The objective is to establish and manage a test station for large wind turbines at Høvsøre on Jutland's west coast. The test station includes five test beds for wind turbines and five meteorology masts at a position 240 m to the west of the test bed row, which is where the prevailing wind comes from. Another meteorology mast is sited 300 m south of the test bed row, and finally there are two 165 m masts equipped with air traffic warning lights.

By the end of 2003, five wind turbines had been erected and were ready for testing at the new Test Station at Høvsøre.

Committee and Expert Group Memberships

Antoniou, I.

Technical Committee 88, Maintenance Team 11; Acoustic noise measurement technique. International Electrotechnical Commission (IEC).

Barthelmie, R.

Convenor, open session on energy, resources and the environment, European Geohysical Society, American Geophysical Union, European Union of Geosciences (EGS/AGU/EUG) Joint Assembly, France, 2003.
Technical Committee, Offshore Wind Energy in Mediterranean and Other European Seas Seminar (OWEMES) 2003.
Atmospheric Aerosols Working Group, American Association for Aerosol Research.

Bjerregaard, E.T.D.

Secretary, the Danish wind energy society (Dansk Selskab for Vindenergi).
Secretary, Technical Committeee and Advisory Committee, the Danish Approval Scheme for Wind Turbines, Danish Energy Authority.
Standardization committee S-588; Elproducerende vindmøller (power generating wind turbines), Danish Standards Association.
Core Group of the Scientific Reference System on Renewable Energy and Energy End-Use Efficiency, Institute for Environment and Sustainability (IES), EU's Joint Research Centre (JRC).

Branner, K.

Committee VI.1; Fatigue Loading, Committee IV.1; Design Principles and Criteria, International Ship and Offshore Structures Congress 2003 (ISSC).

Frandsen, S.

Technical Committee 88, Maintenance Team 12; Wind turbine power performance testing, and Working Group 3; Design requirements for offshore wind turbines, International Electrotechnical Commission (IEC).
Standardization committee S-588; Elproducerende vindmøller (power generating wind turbines), Danish Standards Association.

Gryning, S.E.

Associate editor, 'Quarterly Journal of the Royal Meteorological Society'.
Science Steering Group, BALTEX (the Baltic Sea Experiment).
Conference Committee, 4th Study Conference on BALTEX (the Baltic Sea Experiment), 2004, Bornholm, Denmark.
International Scientific Advisory Committee, 12. Conference on Modelling, Monitoring and Management of Air Pollution, Greece, June 2004. Wessex Institute of Technology.
International Scientific Advisory Committee, 13th Conference on Modelling, Monitoring and Management of Air Pollution, Spain, May 2005. Wessex Institute of Technology.
Secretary, Committee, European Association for the Science of Air Pollution (EURASAP).
Chairman, Executive Committee, Northern Hemisphere Climate Processes Land-Surface Experiment (Nopex).
Scientific Committee, the international conference on Harmonisation within

Atmospheric Dispersion Modelling for Regulatory Purposes.
Scientific Steering Committee, NATO/CCMS International Technical Meetings on Air Pollution Modelling and Its Application (conference series).
Editorial Advisory Board, 'Bulgarian Geophysical Journal'.

Hansen, Anca D.

Reviewer; Wind Engineering (publication), United Kingdom.

Hasager, C.B.

Convenor, symposium on air/land interactions; European Geophysical Society, American Geophysical Union, European Union of Geosciences joint assembly, April 2003, France.
Assessments working group; Global Monitoring for Environment and Security, EC and ESA.
Treasurer, Danish User Group, Erdas Imagine from Leica Geosystems.
Associate scientist, Surface Processes and Ecosystems Changes through Response Analysis (SPECTRA). A land surface satellite space mission proposal for the years 2005-. European Space Proposal (ESA).
Project proposal referee, Aeronautics and space; Sixth Framework Programme, European Commission.
Surface Interactions and Boundary Layer Processes; Division on Atmospheric Sciences, European Geosciences Union (EGU).
Co-convenor, Symposiums on remote sensing in hydrology; Space Observations and Field Experiments; Air/Land Interaction, Nice, 2004. European Geosciences Union (EGU)
Guest editor, Theoretical and Applied Climatology, Springer-Verlag, Wien.
Assessment working group, Global Monitoring Earth System (GMES).

Hauge Madsen, P.

Board member, the Danish wind energy society (Dansk Selskab for Vindenergi).
Chairman, standardization committee S-588; Elproducerende vindmøller (power generating wind turbines), Danish Standards Association.
Convenor, Maintenance Team 1; Safety of wind turbines, and member, Working Group 3; Design requirements for offshore wind turbines, Technical Committee 88, International Electrotechnical Commission (IEC).
Committee on European standards for wind turbines, European Committee for Electrotechnical Standardization (CENELEC).
Editorial Board, 'Wind Energy', Wiley & Sons.
Advisory Committee, the Danish Approval Scheme for Wind Turbines (on behalf of the Danish Standards Association), Danish Energy Authority.
National member, R&D Wind Executive Committee, International Energy Agency (IEA).

Hjuler Jensen, P.

Treasurer, the Danish wind energy society (Dansk Selskab for Vindenergi).
Expert Committee on Wind Turbines and Steering Committee, Wind Turbine Certification, Det Norske Veritas (DNV).
Expert Committee on Wind Turbines, Germanischer Lloyd WindEnergie GmbH (GL Wind).
Technical Committee 88; Maintenance Team 1; Safety of wind turbines, International Electrotechnical Commission (IEC).
Vice-president, European Wind Energy Association (EWEA).

Committee on European standards for wind turbines, European Committee for Electrotechnical Standardization (CENELEC).
Standardization committee S-588; Elproducerende vindmøller (power generating wind turbines), Danish Standards Association.

Højholdt, P.
Technical Committee for Small Wind Turbines, The Danish Approval Scheme for Wind Turbines, Danish Energy Authority.

Højstrup, J.
Vice-chairman, Executive Board; Measuring Network of Wind Energy Institutes (MEASNET).

Jensen, N.O.
National Committee, International Union of Theoretical and Applied Mechanics (IUTAM).
National Committee for the International Geosphere-Biosphere Programme (IGBP).

Jørgensen, E.R.
Steering Committee, Wind Turbine Certification, Det Norske Veritas (DNV).

Jørgensen, H.E.
Vice-president, Dansk Meteorologisk Selskab (the Danish meteorological society).

Kristensen, L.
Associate editor; 'Quarterly Journal of the Royal Meteorological Society'.

Krogsgaard, J.
Governing Council, European Small Hydropower Association (ESHA).

Landberg, L.
Steering Committee, Offshore Wind Energy Network, UK.
Editorial Board, Wind Engineering (publication), UK.
Theme co-ordinator; Meteorology and Wind Energy, Danish Society for Atmospheric Research.
Technical and Scientific Committee, European Academy of Wind Energy Conference 2004, in Delft, Netherlands.
Technical and Scientific Committee, European Wind Energy Conference and Exhibition 2004, in London, United Kingdom.
Technical and Scientific Committee, Global Wind Power 2004, conference and exhibition, Chicago, Illinois, USA.

Larsen, S.E.
Deputy chair, corps of external examiners for physics for Danish universities.
Reviewer, Collaborative Research Opportunities, National Sciences and Engineering Council of Canada.
National Committee, the International Geosphere-Biosphere Programme (IGBP).
Committee on the Marine Aerosol and Gas Exchange (MAGE), subproject of the International Global Atmospheric Chemistry programme (IGAC).
Danish national committee on climate research; subcommittee of the World Climate Research Programme (WCRP).
Steering Committee, Danish Society for Atmospheric Research (DSAR).
Advisory Board, Vejr2 A/S.
Danish national contact for SOLAS (Surface Ocean Lower Atmosphere Study), sponsored by IGBP (International Geosphere Biosphere Programme), WCRP (World

Climate Research Programme) a.o.
Board, the Danish Academy of Wind Energy (DAWE), Danish PhD School.
Board, the Danish Research Consortium for Wind Energy.
Steering Committee, the Nordic Centre of Excellence, research unit on Biosphere/Aerosol/Cloud/Climate Interactions.
Steering Committee, the Nordic Graduate School on Biosphere/Carbon/Aerosol/Cloud/Climate Interactions (CBACCI).

Lundsager, P.

Board, Society of Fuel and Energy Technology, The Society of Danish Engineers (IDA).
Joint Coordination Group for IEC/PAS 62111; Specifications for the use of renewable energies in rural decentralised electrification, on behalf of Technical Committee 88, International Electrotechnical Commission (IEC).

Mann, Jakob

Scientific forum, Danish Technical Research Council, Danish Research Agency

Mikkelsen, T.

Co-convenor. European Geophysical Society (EGS).
Board of Governors, Risø National Laboratory (elected by Risø's academic staff).
Project co-ordinator, 6. Framework Programme on Nuclear Science and Technology, ENSEMBLE, European Commission.

Mortensen, N.G.

Corps of external examiners, University of Copenhagen.
Corps of external examiners, Cairo University.

Nielsen, M.

Webmaster assistant and member, Executive Committee, Dansk Meteorologisk Selskab (the Danish meteorological society).

Nørgård, P.

Society for Technology Assessment, The Society of Danish Engineers (IDA).
Corps of external examiners, Aalborg University, Denmark.

Pedersen, T.F.

Convenor, Technical Committee 88, Maintenance Team 12; Wind turbine power performance testing, International Electrotechnical Commission (IEC).
Standardization committee S-588; Elproducerende vindmøller (power generating wind turbines), Danish Standards Association.
Technical Committee, The Danish Approval Scheme for Wind Turbines, Danish Energy Authority.
Secretary, expert group on power performance measurements, Measuring Network of Wind Energy Institutes (MEASNET).

Petersen, E.L.

European Renewable Energy Centres Agency (EUREC Agency, European Economic Interest Grouping).
Editorial Board, 'International Journal of Sustainable Energy', Taylor & Francis.
Editor, 'Wind Energy', Wiley & Sons.

Rasmussen, F.

Editorial Board, 'Wind Energy', Wiley & Sons.

Skamris, C.

Technical Committee, Danish Type Approval Scheme for Wind Turbines, Danish Energy Authority.

Sørensen, L.L.

Scientific Committee, Integrated approaches to drainage basin nutrient inputs and coastal eutrophication (project), the Nordic Network for Research and Education.

Sørensen, P.

Technical Committee on Energy and Power Systems, 2002-2005, The International Association of Science and Technology for Development (IASTED).

Dynamic Models of Wind Farms for Power System Studies. International Energy Agency (IEA) annex XXI.

Standardization committee S-588; Elproducerende vindmøller (power generating wind turbines), Danish Standards Association.

VEA Publications 2003

International publications

Barthelmie, R.J.; Folkerts, L.; Ormel, F.T.; Sanderhoff, P.; Eecen, P.J.; Stobbe, O.; Nielsen, M., Offshore wind turbine wakes measured by sodar. *J. Atmos. Ocean. Technol.* (2003) v. 20 p. 466-477

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Furevik, B.R.; Espedal, H.A.; Hamre, T.; Hasager, C.B.; Johannessen, O.M.; Jørgensen, B.H.; Rathmann, O., Satellite-based wind maps as guidance for siting offshore wind farms. *Wind. Eng.* (2003) v. 27 p. 327-338

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Granier, A.; Aubinet, M.; Epron, D.; Falge, E.; Gudmundsson, J.; Jensen, N.O.; Köstner, B.; Matteucci, G.; Pilegaard, K.; Schmidt, M.; Tenhunen, J., Deciduous forests: Carbon and water fluxes, balances and ecophysiological determinants. In: Fluxes of carbon, water and energy of European forests. Valentini, R. (ed.), (Springer Verlag, Berlin, 2003) (Ecological Studies, 163) p. 55-70

Gryning, S.-E.; Batchvarova, E., Regional fluxes of momentum and sensible heat over a sub-arctic landscape during late winter. In: Problems of atmospheric boundary-layer physics and air pollution. To the 80th birthday of professor M.E. Berlyand. Chicherin, S.S. (ed.), (Hydrometeoizdat, St. Petersburg, 2002) p. 202-215

Hansen, A.D.; Sørensen, P.; Blaabjerg, F.; Bech, J., Dynamic modelling of wind farm grid interaction. *Wind Eng.* (2002) v. 26 p. 191-208

Hansen, A.D.; Sørensen, P.; Iov, F.; Blaabjerg, F., Initialisation of grid-connected wind turbine models in power-system simulations. *Wind Eng.* (2003) v. 27 p. 21-28

Hansen, K.S.; Larsen, G.C., Wind shear extremes at possible offshore wind turbine locations. *Wind Eng.* (2003) v. 27 p. 339-349

Hansen, M.H., Improved modal dynamics of wind turbines to avoid stall-induced vibrations. *Wind Energy* (2003) v. 6 p. 179-195

Hasager, C.B., Partner 3, Risoe National Laboratory. Annual progress report, 1 February 2002 to 31 January 2003. In: WATERMED - WATer use Efficiency in natural vegetation and agricultural areas by Remote sensing in the MEDiterranean basin. First annual report 1 February 2000 to 31 January 2001. (2003) p. 86-102

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Kristensen, L.; Hansen, O.F.; Højstrup, J., Sampling bias on cup anemometer mean winds. *Wind Energy* (2003) v. 6 p. 321-331

Landberg, L.; Giebel, G.; Nielsen, H.A.; Nielsen, T.; Madsen, H., Short-term prediction - an overview. *Wind Energy* (2003) v. 6 p. 273-280

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Thomsen, C.L.; Kristensen, O.J.D., confidential. Risø-I-2004(EN) (2003) 10 p.

Thomsen, C.L.; Pedersen, H.B., confidential. Risø-I-2007(EN) (2003) 50 p.

Thomsen, K., confidential. Risø-I-1967(EN) (2003) 76 p.

Thomsen, K.; Aagaard Madsen, H.; Rasmussen, F.; Larsen, T.J., confidential. Risø-I-2025(DA) (2003) 96 p.

Thomsen, K.; Antoniou, I.; Larsen, T.J.; Rasmussen, F., confidential. Risø-I-2123(DA) (2003) 34 p.

Thomsen, K.; Fuglsang, P.; Hansen, M.H., confidential. Risø-I-2020(EN) (2003) 51 p.

Thomsen, K.; Larsen, T.J.; Aagaard Madsen, H.; Rasmussen, H., confidential. Risø-I-1973(DA) (2003) 95 p.

Thomsen, K.; Larsen, T.J., confidential. Risø-I-2019(EN) (2003) 23 p.

Vesth, A., confidential. Risø-I-2052(EN) (2003) 49 p.

Educational activities

Barthelmie, Rebecca

Member of the Graduate Supervision Committee for Justin Schoof, Indiana University, Department of Geography 2000-2004.

Bindner, Henrik

Supervisor, PhD student Pedro A. Rosas: *Power quality and stability issues of integration of large wind farms*, Technical University of Denmark.

Branner, K.

Use of FEM in the FastShip-project: Lecture as part of course 41812, *Finite element method-light* (applied finite element modelling). Technical University of Denmark.

External examiner, MSc thesis by Veine Huth & Robert Skaar: *Effect of wrinkle defects on the compressive strength of CFRP laminates in sandwich structures*, Technical University of Denmark, Dept. of Mechanical Engineering.

Supervisor, PhD student Find Mølholt Jensen: *Ultimate strength of large wind turbine blade*, Technical University of Denmark.

Christiansen, Merete B.

Remote sensing I, exercises, University of Copenhagen, Institute of Geography.

Aeolian geomorphology, lectures, University of Copenhagen, Institute of Geography.

Clausen, N-E.

Wind farm planning in the Gulf of Suez: Lecture, NREA workshop, Cairo, Egypt.

Evaluation of the impact of climate change on wind energy: Lecture, Nordic research project CWE/CE workshop, Reykjavik, Iceland.

Planning, development and implementation of offshore wind energy projects: course for technical staff and industry.

Preparation of wind turbine projects in Danmark and abroad; Feasibility analysis of a wind turbine project; Danish and international environmental approval (VVM and EIA): Lectures in Danish, Herning Institute of Business Administration and Technology.

Gryning, S.E.

Aspects of air pollution in a gulf: Meteorology, orography and management. Lecture at the Aqaba Special Economic Zone Authority, Environmental Studies and Monitoring Division, Jordan.

Faculty opponent at the PhD defence of Xioali Guo Larsén, *Air/sea exchange of momentum and sensible heat over the Baltic Sea*, Uppsala University, Sweden.

Hansen, Anca D.

Control (Styring og regulering). Lecture in Danish, Herning Institute of Business Administration and Technology, HIBAT-Wind.

Control (Styring og kontro)l: Lecture in Danish, Herning Institute of Business Administration and Technology.

Hansen, Jens C.

Wind measurements, data handling and wind resource estimations. Two-day training programme as part of the project *Wind meaurements and wind power feasibility at selected sites in Tanzania*.

Hansen, Morten H.

Aeroelasticity for wind turbines – dynamic stability: Lecture as part of course 41322, *Projects in wind turbine aeroelasticity*, Technical University of Denmark.
Experiments with wind turbines: Course 41811, *Experimental solid mechanics*, Technical University of Denmark.

Hasager, Charlotte B.

External examiner: MSc thesis, remote sensing, University of Copenhagen, Institute of Geography.
External examiner: Microclimatology, University of Copenhagen, Institute of Geography.
External examiner: MSc thesis, Roskilde University, Dept. of Geography and International Development Studies.
External examiner: MSc thesis in physical geography, Roskilde University, Dept. of Geography and International Development Studies.
External examiner: Three bachelor projects. University of Copenhagen, Institute of Geography.
Evaluation panel: two scientific positions at the National Environmental Research Institute, Department of Atmospheric Environment, Denmark.
Supervisor, PhD student Merete Bruun Christiansen: *Satellite sensing of offshore wind*, University of Copenhagen.

Højstrup, Jørgen

Offshore wind and turbulence: course, Vestas Wind Systems A/S, Denmark.
Verification of a wind turbine's power curve. IEC 61400-122. Lecture in Danish. Herning Institute of Business Administration and Technology.
Calculation of the energy generation from af wind farm. Case studies in Danish. Herning Institute of Business Administration and Technology.
Meteorology and measurements: course in Danish for VEA and DNV.

Jauch, Clemens

Wind power technology 1: MSc course in sustainable energy engineering, Aalborg University.

Jensen, Find M.

Buckling theory of shell/ plates. Elementary cases. FEM (finite element method) training. Parameter studies. Preparation of report: Lectures as part of the course *Buckling of curved composite plates and shells*, 10 ECTS points, Risø National Laboratory.
Industrial use of FEM. Finite element method light course in Danish, Technical University of Denmark, Dept. of Mechanical Engineering.

Jensen, Niels Otto

Supervisor, PhD student Ebba Dellwik, *Development of a microscale SVAT model over a closed beech forest canopy*, Technical University of Denmark.

Johansen, Jeppe

Use of computational fluid dynamics on wind turbine aerodynamics: Lecture, Aalborg University.

25 years of wind power in Denmark – well started! Lecture in Danish, Musicon Valley Vækstmiljø.

Supervisor, PhD student Frederik Zahle: *Investigation of rotor/tower interaction using CFD modelling*, Imperial College, University of London.

Landberg, Lars

Wind energy and meteorology: Lecture, Technical University of Denmark, Dept. of Mechanical Engineering.

Supervisor, PhD student Alfred Joensen: *Short-term wind power prediction*, Technical University of Denmark.

Larsen, Søren E.

Climate, meteorology, boundary layers: Lecture at the PhD summer school of the Danish Academy of Wind Energy (DAWE),

External examiner: *Global climate changes*: Course 321 at the Department of Geophysics, University of Copenhagen

External reviewer, PhD thesis *Influence of external factors on the turbulence structure in boundary layers*, C. Johansson, Uppsala University, Department of Earth Sciences.

External reviewer, PhD thesis *Short term prediction*, A. Joensen, Institute of Mathematical Methods, Technical University of Denmark.

External reviewer, Lic. thesis *Wave loads on offshore structures*, J. Trumars, Chalmers University of Technology, Sweden.

Mann, Jakob

Supervisor, PhD student Jacob Berg Jørgensen: *Particle tracking studies of turbulence and wind motion*, University of Copenhagen.

Myllerup, Lisbeth

Supervisor (in collaboration with Bo H. Jørgensen and Lars Landberg), PhD student Jean-Francois Corbett: *Modelling of wind flow over complex terrain*, University of Copenhagen.

Nørgård, Per B.

Nysted Offshore Wind Farm: technical excursion as part of the one-week course *Specific wind power planning, development and implementation aspects* with participants from ITRI, Taiwan.

25 years of wind power in Denmark – well started! Lecture in Danish, Musicon Valley Vækstmiljø.

Wind measurements, data handling and wind resource estimations. Two-day training programme as part of the project *Wind meaurements and wind power feasibility at selected sites in Tanzania*.

Paulsen, Uwe S.

Wind turbine measurement techniques: course 31395. Lectures at the Technical University of Denmark.

Pedersen, Troels F.

Wind speed measurements course: Lecture, part of MSc course in wind energy, Technical University of Denmark.

Power performance measurements on wind energy installations: short-term course for engineers in metrology, Metrologia 2003, Brazil.

Schaarup, Jesper H.

Wind turbine foundation, towers (Fundering af vindmøller, tårne): Lecture in Danish, Herning Institute of Business Administration and Technology, HIBAT-Wind, Denmark.

Sørensen, Lise Lotte

Supervisor, MSc thesis in Danish: *Atmospheric gas transport to Kattegat by the sea and land breeze circulation*, Jesper Nissen, University of Copenhagen.

Deposition of particles: lecture as part of the MSc- PhD-level course *Air/sea exchange from a biogeochemical and climate perspective*. NORFA Network for Atmospheric Aerosol Dynamics (NAD), Sweden.

Air pollution: MSc course in Danish, Aalborg University, Dept. of Life Sciences, Section of Environmental Engineering.

Sørensen, Niels N.

Supervisor, PhD student Andreas Hansen: *Flow over complex terrain*, Technical University of Denmark.

Supervisor, PhD student Giovanni Fatigati: *Laminar turbulent transition*, Technical University of Denmark.

Sørensen, Poul E.

Supervisor, PhD student Clemens Jauch: *Stability and control of wind farms in power systems*, Aalborg University.

Supervisor, PhD student Sigrid Bolik: *Advanced modelling and control of variable speed wind turbines with induction generators*, Aalborg University.

Supervisor, PhD student Pedro A. Rosas: *Power quality and stability issues of integration of large wind farms*, Technical University of Denmark.

Wind turbine technology, two-days course for technical staff, Electricity Supply Board, Dublin, Ireland.

Styring og kontrol: Lecture, Herning Institute of Business Administration and Technology, HIBAT-Wind.

Wind power technology and influence on power quality: Lecture, MSc course 31395, *Wind turbine measurement technique*, 5 ECTS points. Technical University of Denmark.

The electric design of wind farms (Vindkraftanlægs elektriske opbygning)/ Wind farm and grid interaction (Vekselvirkning mellem vindkraftanlæg og elsystem)/ Control (Styring og regulering)/Measurement techniques (Måleteknik): three basic courses in Danish for recently employed engineers in the wind turbine industry, Herning Institute of Business Administration and Technology, HIBAT-Wind.

Wind power technology. Wind energy development and technical challenges: MSc

course in sustainable energy engineering. Institute of Energy Technology, Aalborg University.

Wind power technology. Technology overview. MSc course in sustainable energy engineering. Institute of Energy Technology, Aalborg University.

Thomsen, Kenneth

Wind turbine design loads: MSc course in wind energy. Technical University of Denmark.

Design survey: Basic course in Danish for recently employed engineers in the wind turbine industry. Herning Institute of Business Administration and Technology, HIBAT-Wind.

Thykier-Nielsen, Søren

LSMC/RIMPUFF model chain for calculations of dispersion: Lecture in Danish, ARGOS specialist/authorities course. Snekkersten, Denmark.

Seminars in the department

7 January
Thomas Buhl:
Design of non-linear mechanisms – topology and shape optimization.

10 March
Ian F. Jones, Director, Ocean Technology Group, University of Sydney, Australia:
Managing climate change by sequestration.

18 March
Anna Maria Sempreviva:
Comparison of the wind climatology offshore in the Mediterranean basin from three models.

22 April
Ebba Dellwik:
Wind and temperature profiles over forest.

23 May
Jose D. Fuentes, Associate Professor, Department of Environmental Sciences, University of Virginia, USA:
Phytogenic hydrocarbons, aerosols, and radiative forcing.

19 August
Torben Mikkelsen:
A bi-static SODAR called 'Heimdall'.

26 August
Sven-Erik Gryning:
Roof-level urban tracer experiment; measurements and modelling.

2 September
Gregor Giebel:
The state of the art in short-term prediction – including some lesser known models.

9 September
Ferhat Bingöl:
En vinddatabase til VEA (A wind-database for VEA.)

16 September
Jacob Berg Jørgensen:
Abrupt climate change.

23 September
Morten Hartvig Hansen:
Linear and non-linear stability of wind turbines.

30 September
Sten Frandsen:
Fatigue in wind farms; justification of application model.

2 October
Nick Ouellette, Department of Physics, Cornell University, USA:
3D Lagrangian acceleration measurements in fully developed turbulence.

7 October
Frank Bradley, CSIRO (Commonwealth Scientific and Industrial Research Organisation), Australia:
Storms, rainfall and sea temperature during EPIC 2001.

21 October
Alexei Stulyi, University of Svalbard, Norway:
Inferring coherent turbulent motions in the convective atmospheric boundary layer (CABL) from the SAR imagery.

28 October
Charlotte Bay Hasager:
Winds from satellite SAR and WAsP add-on software.

30 October
Eva Bøgh, Institute of Geography, University of Copenhagen:
Remote sensing based estimation of leaf area index and nitrogen concentration for CO_2 flux modelling.

11 November
Niels Jacob Tarp-Johansen:
Extreme response of wind turbines.

18 November
Xiaoli Guo Larsén:
Air/sea exchange of momentum and sensible heat over the Baltic Sea.

2 December
Hans E. Jørgensen:
Vejret på Mars (The weather on Mars).

4 December
James E. Tillman, Research Professor Emeritus, Dept. of Atmospheric Sciences, University of Washington, Seattle, USA:
The Martian boundary layer and climate: Great dust storm characteristics and their forecast from Viking analyses, past, present and future.

9 December
Leif Kristensen:
Power loss in the upper cut-out wind speed interval.

16 December

Andreas Hansen:
Modstandsanalyse for planende skibe – panelmetode (Resistance analysis for the panel method on planing ships).

17 December
Beat Lüthi, Dr., Swiss Federal Institute of Technology, Switzerland:
Velocity derivatives from 3D-PTV in turbulent flow, or
Strain, enstrophy and material element dynamics from 3D-PTV.

Staff and Guests 2003

Administration (LAM)

Erik Lundtang Petersen*, Head of Department*
Peter Hauge Madsen, *Deputy Head of Department*
Gitte Clausen, *Project Administrator*
Karen Hyllested Thielsen, *Administrative Officer*
Else Holst Sørensen, *Librarian*
Helle Hedegaard, *Receptionist*
Birgitte D. Johansen, *Consultant*

Secretary

Ulla Riis Christiansen, *Department secretary*

Aeroelastic Design (AED)

Scientific staff

Flemming Rasmussen*, Head of Programme*
Christian Bak
Franck Bertagnolio
Thomas Buhl
Peter Fuglsang
Gaunaa, Mac
Anders Melchior Hansen
Morten, Hartvig Hansen
Jeppe Johansen
Gunner Chr. Larsen
Torben Juul Larsen
Helge Aagaard Madsen
Niels Nørmark Sørensen
Kenneth Thomsen
Jess Michelsen

Secretary

Tina M. Precht

Meteorology (MET)

Scientific staff

Lars Landberg*, Head of Programme*
Poul Astrup
Sven Erik Gryning
Charlotte Bay Hasager
Niels Otto Jensen

Hans Jørgensen
Søren Larsen
Torben Mikkelsen
Morten Nielsen
Sara Pryor
Lise Lotte Sørensen
Søren Thykier-Nielsen
Jake Badger
Rebecca Barthelmie
Gregor Giebel
Bo Hoffmann Jørgensen
Jakob Mann
Niels Gylling Mortensen
Lisbeth Myllerup
Søren Ott
Ole Rathmann
Anna Maria Sempreviva

Sales co-ordinator

Rikke Nielsen

Secretary

Anette Werner

Wind Energy Systems (VES)
including Risø Wind Consult (INR)

Scientific staff

Jens Carsten Hansen, *Head of Programme*
Henrik W. Bindner
Anca Daniela Hansen
Per Nørgaard
Poul Sørensen
Anders Johansen
Niels Erik Clausen
Per Lundsager
Oliver Gehrke

Secretaries

Jytte Madsen
Diana Kiler

Wind Turbines (VIM)

Scientific staff

Peter Hjuler Jensen, *Head of Programme*
Per Harvøe
Egon Bjerregaard

Christian Debel
Sten Tronæs Frandsen
Erik Rosenfeldt Jørgensen
Thomas Krogh
Jesper Schaarup
Niels Jacob Tarp-Johansen
Kim Branner
Christian Jensen

Technical staff

Rolf Lange

Secretaries

Bodil Bødker
Kirsten Westermann

Test and Measurements (TEM)

Scientific staff

Jørgen Højstrup, *Head of Programme*
Ioannis Antoniou
Karen Enevoldsen
Ole Frost Hansen
Jørgen Krogsgaard
René Møller
Troels Eske Nielsen
Uwe Schmidt Paulsen
Troels Friis Pedersen
Søren Markkilde Petersen, *Head of Task*
Peter Sanderhoff
Allan Vesth

Technical staff

Anker Bruun Andersen
Jens Borchsenius
Kurt Christensen
Lars Christensen
Kasper Clemmensen
Finn Hansen
Per Hansen
Oluf Høst
Gert Larsen
Søren W. Lund
Finn Linke Nielsen
Jan Nielsen
Michael Rasmussen

Secretary

Anne-Marie Hansen

Sparkær Blade Test Centre (SPK)

Carsten Skamris*, Head of Programme*
Yoram Eisenberg
Jan Hornbech
Ole Dahl Kristensen
Henrik Broen Pedersen
Christian Leegaard Thomsen
Mads Holler Foget
Peter Henrik Lind, *Works Foreman*
Jimmy Holm Stær
Anders Ramsing Vestergaard
Bruno Svendsen
Secretary
Bente Hangaard Kristensen

PhD students, graduates, and postdoctoral researchers

Sigrid Bolik, *PhD student, VEA supervisor: Poul E. Sørensen*
Merete Bruun Christiansen, *PhD student, VEA supervisor: Charlotte Bay Hasager*
Jean-Francois Corbett, *PhD student, VEA supervisors: Lisbeth Myllerup and Bo Hoffmann Jørgensen*
Ebba Dellwik, *PhD student, VEA supervisor: Niels Otto Jensen*
Giovanni Fatigati, *PhD student, VEA supervisor: Niels N. Sørensen*
Andreas Hansen, *PhD student, VEA supervisor: Niels N. Sørensen*
Clemens Jauch, *PhD Student, VEA supervisor: Poul E. Sørensen*
Find Mølholt Jensen, *PhD student, VEA supervisor: KimBranner*
Alfred Joensen, *PhD student, VEA supervisor: Lars Landberg*
Jacob Berg Jørgensen, *PhD student, VEA supervisor: Jakob Mann*
Pedro André Rosas, *PhD student, VEA supervisors; Poul Sørensen and Henrik Bindner*
Frederik Zahle, *PhD student, VEA supervisor; Jeppe Johansen*

Xiaoli Guo Larsén, *postdoc*

Maurizio Motta, *guest scientist*

Sune Djuurhus, *trainee*

Santiago Basualdo, *student*
Ferhat Bingöl, *student*
Brian Riget Broe, *student*
Martin Christoffersen, *student*
Tom Cronin, *student*
Régis Danielian, *student*

Ali Sherif Elsayed, *student*
Gabriele Gail, *student*
Anastasios Gkinis, *student*
Klaus Nygaard Jørgensen, *student*
Timothy Knill, *student*
Jesper Nissen, *student*
Daniel Pardo, *student*
Mikkel Rasmussen, *student*

Guests

Chandra S. Chekuri; Chennai, India
Hannele Holttinen; VTT Technical Research Centre of Finland, Finland

Wind Energy Department 2003 in brief

The overall objective of the Wind Energy Department is to create new opportunities for technological development and the utilization of wind energy through research, innovation, education, testing, and consultancy.

Our research and development activities cover a variety of topics from boundary layer meteorology and fluid dynamics to structural mechanics, power and control engineering as well as wind turbine loading and safety. It is our aim to meet the needs for knowledge, methods and consultancy services in relation to wind energy, and we are involved in technology development as well as the operation and maintenance, testing, and certification of wind turbines. Furthermore, we look into technical problems related to the application of wind energy. A major part of this work is carried out on a commercial basis.

Department activities also include research into environmental issues related to the atmosphere.

Organization

Department management:

Erik Lundtang Petersen, Head (ext. 5001)

Peter Hauge Madsen, Deputy Head (ext. 5011)

Research is organized in the following programmes:

Meteorology
Lars Landberg, Head (ext. 5024)

Aeroelastic Design
Flemming Rasmussen, Head (ext. 5048)

Wind Energy Systems
Jens Carsten Hansen, Head (ext. 5011)

Wind Turbines
Peter Hjuler Jensen, Head (ext. 5037)

Test and Measurements
Jørgen Højstrup, Head (ext. 5092)

Commercial activities are:

Wind Turbine Testing
Søren Markkilde Petersen, Head (ext. 5043)

Sparkær Blade Test Centre
Carsten Skamris, Head (ext. 5066)

Risø Wind Consult
Jens Carsten Hansen, Head (ext. 5074)

Høvsøre Test Station
Carsten Skamris, Head (ext. 5066)

Publications

Refereed international publications	43
International books and reports	5
Danish books and reports	135
Conference papers with proceedings	65
Patent applications	1

Wind Energy Department at Risø National Laboratory
Building VEA-118, PO box 49, 4000 Roskilde, Denmark
Phone +45 4677 4677, telefax +45 4677 5083
e-mail vea@risoe.dk, web address www.risoe.dk/vea

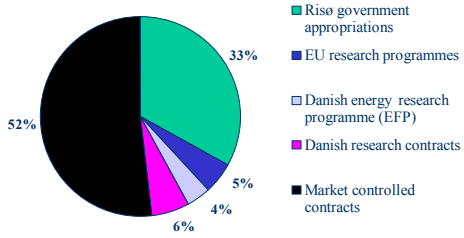
Finances

Turnover	DKK 100.1 million
Contracts, market controlled	DKK 52.1 million
Contracts, grant controlled	DKK 14.9 million

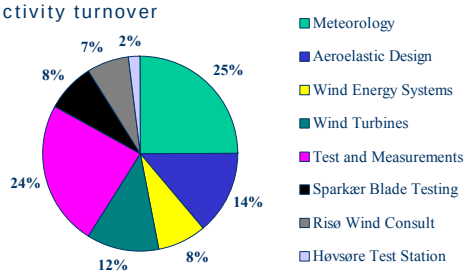
Staff

Academic staff	78
Technical/administrative staff	25
PhD and postdocs	5

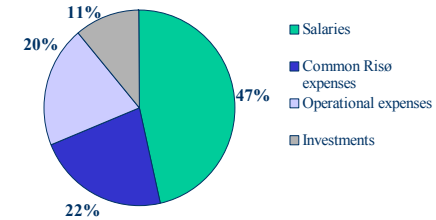
Funding sources



Activity turnover



Expenses



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Abstract: This report covers the scientific work of the Wind Energy Department in 2003. It comprises departmental programmes as well as brief summaries of all non-confidential projects and a review of the key issues of 2003.